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ABSTRACT

The rate training manual provides information related to the tasks assigned to the Interior Communications (IC) Electricians Third and Second Class who operate and maintain the interior communications systems and associated equipment. Chapter one discusses career challenges for the IC Electrician in terms of responsibilities, advancement qualifications; naval training publications; and basic rules for studying. Chapters two through nineteen, illustrated throughout with photographs and diagrams, cover safety; switches, protective devices, and cables; power distribution systems; test equipment; sound-powered telephones; alarm and warning systems; announcing and intercommunicating systems; dial telephone systems; sound recording and reproducing systems; gyrocompasses; ships control order and indicating systems; ships metering and indicating system; plotting systems; maintenance; new installations and equipment; and closely regulated power supplies. A section on security, a glossary of computer terms, and a key to electronics symbols are appended. (Author/BP)

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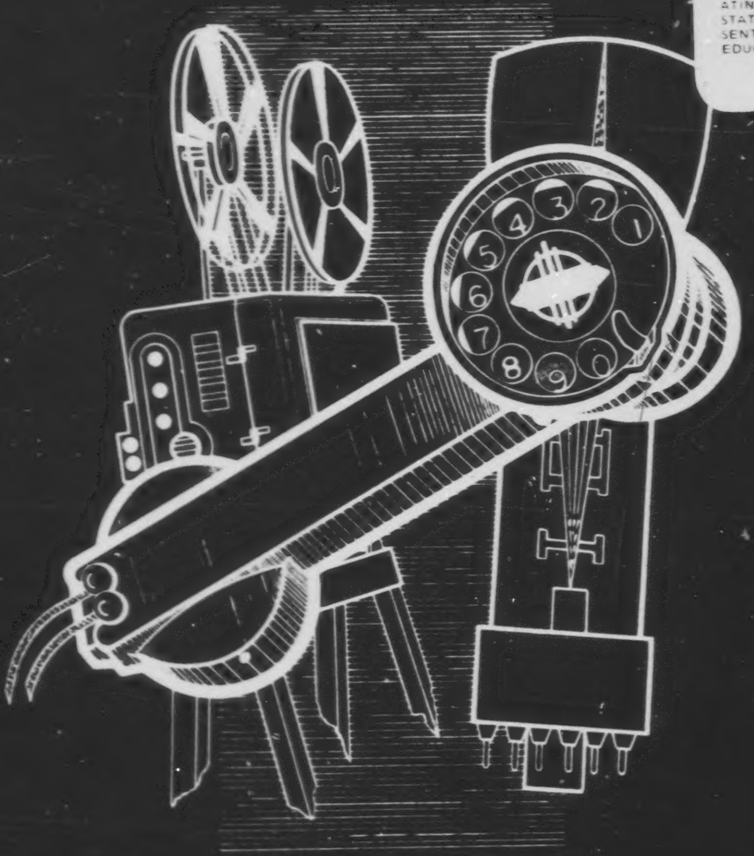

IC ELECTRICIAN 3 & 2

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL

NAVEDTRA 10558-B

PREFACE

The primary purpose of training is to produce a combat Navy which can maintain control of the sea and guarantee victory. Victory at sea depends upon the state of readiness of shipboard personnel to perform tasks assigned to them in accordance with the needs of the ship. This Rate Training Manual provides information related to the tasks assigned to the IC Electricians Third and Second Class who operate and maintain the interior communications systems and associated equipment. It is only when shipboard personnel can and do perform their tasks efficiently that each ship will be operating at a high state of readiness and adding her contribution which is essential to guarantee victory at sea. As an IC3 or IC2, you will be expected to know the information in this manual and to perform your assigned tasks. The degree of success of the Navy will depend in part on your ability and the manner in which you perform your duties.

This manual was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Information provided by numerous manufacturers and technical societies is gratefully acknowledged. Technical assistance was provided by the Naval Ship Engineering Center, Washington; Service School Command, San Diego; Service School Command, Great Lakes; and Fleet Training Center, Norfolk.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

CHAPTER | Page

1. Career Challenges for the IC Electrician 1
2. Safety. 8
3. Switches, Protective Devices, and Cables 31
4. Power Distribution Systems 86
5. Test Equipment 114
6. Sound-Powered Telephones 147
7. Alarm and Warning Systems 171
8. Announcing and Intercommunicating Systems 193
9. Dial Telephone Systems, Part I 235
10. Dial Telephone Systems, Part II 274
11. Sound Recording and Reproducing Systems 289
12. Gyrocompasses, Part I 305
13. Gyrocompasses, Part II 343
14. Ships Control Order and Indicating Systems 372
15. Ships Metering and Indicating System. 383
16. Plotting Systems. 419
17. Maintenance 458
18. New Installations Equipment 497
19. Closely Regulated Power Supplies. 520

APPENDIX

I. Security 550
II. Glossary of Computer Terms 555
III. Electronics Symbols. 557

INDEX 560

CREDITS

The illustrations indicated below are included in this edition of IC Electrician 3 & 2 through the courtesy of the designated companies. Permission to use these illustrations is gratefully acknowledged.

SOURCE	FIGURES
Gems Co., Inc.	3-19
Jones Motrola Corp & Bert A. Shields	5-14
James G. Biddle Co.	5-15
General Radio Co.	5-16
U. S. Instrument Co.	6-7, 6-8, and 6-11

CHAPTER 1

CAREER CHALLENGES FOR THE IC ELECTRICIAN

This Rate Training Manual is intended to help you develop your technical skills, since it is the knowledge and skill of men like yourself that make our modern Navy possible. By learning the information in this manual and gaining practical experience on the job, you will prepare yourself for a successful and rewarding Navy career. The Navy has developed a training system to help you learn the duties of the next higher grade in your rating. When you can demonstrate, by your performance on the job, by your mastery of the required skills, and by written examination, that you are well qualified to perform these duties, you will be advanced. Even as you are working toward advancement the extra effort and study that you devote to learning your rate will reward you in terms of greater job satisfaction, and by your becomming able to do more important and interesting work.

Work in interior communications (IC) concerns the inventions of several engineers and scientists of the 19th and 20th centures; the telephone of Bell, Sperry's gyrocompass, and induction devices pioneered by William Sturgeon. As with any electrical work, the theories of Georg Ohm and Alesandra Volta are applied daily. It is common for the IC Electrician to use routinely concepts which a hundred years ago were as advanced as the theories of Einstein are today.

Your training for the IC Electrician rating will include electronics and electrical theory, and fundamentals of operation of motors, generators, alarms, sensors, telemetering systems, and other electrical equipment. You must become proficient in using handtools and electrical measuring instruments. In troubleshooting IC systems, for example, you must be able to read and work from blueprints and electrical schematics and analyze the performance of a circuit and its components.

THE IC ELECTRICIAN RATING

Before World War II the interior communications of a ship consisted of sound-powered phones, automatic telephones, general announcing systems, and synchronous telegraph systems. These were cared for by Electrician's Mates, who could receive special training through a gyrocompass class B school and an interior communications class B school.

During World War II the trainees in the IC class B school studied algebra, trigonmetry, gyrocompasses, movie projectors, automatic telephones, and synchro systems. They were also required to build a 50-watt amplifier.

The rapid advances in interior communications and navigation equipment during World War II led to the establishment of the IC rating in 1948. To train men in the new rating an IC class A school was established at Great Lakes, Ill., and another at San Diego, Cal. In 1957 the IC class B school moved from Washington, D.C. to its present location, the Great Lakes, Naval Training Station. The number of IC class C schools has increased to eight as more sophisticated communications systems and navigational tracking systems have been developed.

The IC Electrician rating is a general rating, and is not divided into service ratings. (An example of a rating divided into service ratings is the ET; its service ratings are the ETN and the ETR. The ETN specializes in communications equipment, the ETR specializes in radar.)

RESPONSIBILITIES OF TODAY'S IC ELECTRICIAN

Modern warships are capable of defending themselves against supersonic aircraft and missiles. The ships have complex interior communications systems to carry information between their various control and command centers.

These systems are vital to a warship's combat readiness and safety.

As defined in the Manual of Qualifications for Advancement or so-called Quals Manual, the scope of the IC rating is:

> "Interior Communications Electricians operate and perform organizational and intermediate maintenance on interior communications systems including voice interior communications, alarm, warning, ship's control,entertainment, gyrocompass, and plotting; stand watch on related equipment, and ensure the enforcement of safety precautions."

The qualifications of the IC Electrician are oriented to shipboard duties; he is found on almost all naval vessels. Ashore, he may work in his rating in a repair facility or as an instructor, but is just as likely to be working outside his rating in a duty, such as shore patrol or recruiting.

The requirements for advancement outlined by the Quals Manual are designed to ensure that an IC Electrician assigned to any ship in the fleet will have the general qualifications to perform his assigned duties. Since some ships, particularly the more modern ones, have special interior communications equipment, the IC Electricians assigned to them must have special training. A Navy Enlisted Classification (NEC) coding system helps identify the men who have this special training.

NAVY ENLISTED CLASSIFICATION CODES

Though your rate shows what you are qualified to do, it does not by itself show any of your special qualifications or skills, either within your rate or outside of it. NECs are used to show significant qualifications not shown by the rate designation. The NEC coding system identifies special qualifications through a four digit number, such as IC 4712 or IC 4724. Not everyone in the Navy has a special code number, but some individuals have more than one, depending on their qualifications. The qualification considered to be the most important is identified by the first code number; the one considered to be of secondary importance by the second code number. These code numbers can be obtained by completing special training or class C schools.

Some of the NECs that may be assigned to qualified IC Electricians and applicable courses they must complete are:

IC 4712 Automatic Telephone Repairman
Applicable Course: Automatic Telephones, Class C (A-623-0014)

IC 4722 Gyrocompass (Mechanical) Technician
Applicable Course: Gyrocompass Technician (Mechanical), Class C (A-670-0014)

IC 4724 Gyrocompass (Electrical) Technician
Applicable Course: Gyrocompass Technician (Electrical), Class C (A-670-0021)

IC 4746 Closed-Circuit TV Technician
Applicable Course: Closed Circuit TV Maintenance, Class C (A-198-0020)

For more information on obtaining NECs, you should contact your leading petty officer or personnel office.

QUALIFICATIONS FOR ADVANCEMENT

As an IC Electrician you will perform both military and professional duties. The military requirements and professional qualifications for all ratings in the Navy are listed in the Quals Manual which is periodically revised to reflect organizational and procedural changes in the Navy that affect the ratings, and to incorporate additional skills and techniques required by the development and installation of new equipment.

The military duties for the IC Electrician are the same as those for other petty officers. This Rate Training Manual primarily concerns the professional duties of IC Electricians and does not attempt any detailed consideration of the military duties. The military requirements are discussed in Military Requirements for Petty Officer 3 & 2. Figure 1-1 shows the requirements for advancement of active duty personnel; figure 1-2 does the same for inactive duty personnel.

The professional or technical duties performed by the IC Electrician include a variety of tasks that require many specialized skills and techniques necessary to perform properly the occupational duties of his rate. The professional qualifications for the IC rating have been used as a guide in preparing this Rate Training Manual and will be used by the Naval Examining Center in constructing the servicewide competitive examinations. In preparing to take these examinations you should consult the latest revision of the Quals Manual for changes distributed after the publication of this Rate Training Manual. The next change to the Quals Manual for the IC rating is scheduled for distribution in June 1977.

REQUIREMENTS *	E1 to E2	E2 to E3	# E3 to E4	#† E4 to E5	† E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service–or completion of Recruit Training.	8 mos. as E-2.	6 mos. as E-3.	12 mos. as E-4. 3 years time in service.	24 mos. as E-5. 6 years time in service.	36 mos. as E-6. 8 years time in service.	36 mos. as E-7. 8 of 11 years time in service must be enlisted.	24 mos. as E-8. 10 of 13 years time in service must be enlisted.
SCHOOL	Recruit Training. (C.O. may advance up to 10% of graduating class.)	▨	Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3,	▨	▨	Class B for AGC, MUC, MNC.††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NavEdTra 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST	▨	▨	Specified ratings must complete applicable performance tests before taking examinations.				▨	▨
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS **	Locally prepared tests.	See below.	Navy-wide examinations required for all PO advancements.			Navy-wide selection board.		
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	▨	Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavEdTra 10052 (current edition).					Nonresident career courses and recommended reading. See NavEdTra 10052 (current edition).	
AUTHORIZATION	Commanding Officer		NAVEDTRA PRODEVCEN					

* All advancements require commanding officer's recommendation.

† 1 year obligated service required for E-5, and E-6; 2 years for E-7, E-8, and E-9.

# Military leadership exam required for E-4 and E-5.

** For E-2 to E-3, NAVEDTRAPRODEVCEN exams or locally prepared tests may be used.

†† Waived for qualified EOD personnel.

Figure 1-1.—Active duty advancement requirements.

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	8 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavEdTra 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		NAVEDTRA PRODEVCEN					

*Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for training duty.

Figure 1-2. — Inactive duty advancement requirements.

SOURCES OF INFORMATION

No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating. Information related to requisitioning materials, required maintenance forms, leadership and supervision should be obtained from Military Requirements for Petty Officer 3 & 2.

Some of the publications described here are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance; it is likely to be a waste of time, and may even be seriously misleading.

You must bear in mind, however, that you cannot depend on the printed word alone; you must supplement the information you obtain from books with actual practice, and with the knowledge acquired from observing experienced men at work.

NAVAL TRAINING (NAVEDTRA) PUBLICATIONS

Effective 15 January 1972, the Naval Training Support Command and its field activities came directly under the command of the Chief of Naval Training instead of the Chief of Naval Personnel. Training materials published by the Naval Training Support Command after the above date are designated NAVEDTRA in lieu of NAVPERS; in most cases, the numbers remain as originally assigned. The designators of publications printed before the above date will be changed as each publication is revised.

The naval training publications described here include some that are absolutely essential for meeting your job requirements and some that are extremely helpful, although not essential.

Bibliography for Advancement Study NAVEDTRA 10052

This pamphlet provides a working list of material for enlisted personnel who are studying for their advancement examinations. It is revised and issued annually by the Naval Education and Training Support Command. Each revised edition is identified by a letter following the NAVEDTRA number. When using the bibliography, be sure you have the most recent edition.

The working list contains required and recommended Rate Training Manuals and other references. A Rate Training Manual marked with an asterisk (*) in NAVEDTRA 10052 is MANDATORY at the indicated rate level. Remember, however, that you are responsible for all references at lower levels, as well as those listed for the rate to which you are seeking advancement. A mandatory Rate Training Manual may be completed by (1) passing the appropriate nonresident career course (formerly called correspondence course), based on the manual, (2) passing locally prepared tests based on the mandatory training manual, or (3) in some cases, successfully completing an appropriate Navy school.

All references, whether mandatory or recommended, listed in NAVEDTRA 10052 may be used as source material for the written advancement examination, at the appropriate levels. In addition, references cited in a mandatory or recommended Rate Training Manual may be used as source material for examination questions.

Rate Training Manuals

These manuals help enlisted personnel fulfill their job requirements as expressed by the practical and knowledge factors that they must acquire for advancement. Some manuals are general, and intended for more than one rating; others, such as this one, are specific to the particular rating.

Rate Training Manuals are revised from time to time to bring them up-to-date. The revision of a Rate Training Manual is identified by a letter following the NAVEDTRA number. You can tell whether a Rate Training Manual is the latest edition by checking the NAVEDTRA number and the letter following the number in the most recent edition of the List of Training Manuals and Correspondence Courses, NAVEDTRA 10061 (revised).

DOD INFORMATION SECURITY PROGRAM REGULATION

This regulation or DODISPR (for short) is the basic directive for administering the Information Security Program throughout the Department of

Defense. It ensures the protection of official DOD information relating to national security. DODISPR is supplemented by OPNAV INSTRUCTION 5510.1D to provide necessary instructions and policy guidance for the Department of the Navy. The format of the Navy supplement corresponds to that of DODISPR, except that the supplement contains additional information which concerns the Department of the Navy Information Security Program. DODISPR and OPNAVINST 5510.1D supersede the canceled Navy Security Manual for Classified Information. Appendix I of this Rate Training Manual contains basic principles of security relative to the access, dissemination, storage, transmission, compromise, and destruction of classified material.

TECHNICAL MANUALS

Although much of your work will be routine, you will always face new problems, and have to look up information to solve them. The log room of your ship will contain a comprehensive technical library. The books in this library are primarily designed for the engineer officer to use, but you will have occasion to use them. Manufacturers' technical manuals for most of the equipment in the ship will be found in the log room library. They are valuable sources of information on operation, maintenance, and repair.

The "encylopedia" of Navy engineering—Naval Ship Systems Command Technical Manual or so-called NAVSHIPS Tech Manual,—is also kept in the log room. Unless assigned to work there, you will not have an opportunity to study the NAVSHIPS Tech Manual, so all the information in it relating to your advancement requirements is included in this Rate Training Manual. There are occasions, however, when you will have to use the NAVSHIPS Tech Manual and manufacturers' technical manuals, such as, when you are assigned responsibilities for equipment with which you are not familiar or have to perform complex maintenance or repair operations which you have not done before.

PERIODICALS

The Naval Ship Systems Command Techanical News is a monthly publication with useful articles on all aspects of shipboard engineering. It supplements and clarifies information contained in the NAVSHIPS Tech Manual and also presents information on new developments.

Safety Review, published monthly by the Naval Material Command, contains information on the safe storage, handling, or other use of products and materials. Fathom, published quarterly by the Naval Safety Center, provides accurate, and current information on nautical accident prevention.

The Electronics Information Bulletin (EIB) is published biweekly by the Naval Ship Engineering Center. EIB articles contain advance information on field changes, installation techniques, maintenance notes, beneficial suggestions, and technical manual distribution. Articles of lasting interest are transcribed into the Electronics Installation and Maintenance Book (EIMB). The EIMB is a single-source reference document of maintenance and repair policies, installation practices, and overall electronics equipment and material-handling procedures for implementing the major policies set forth in chapter 9670 of NAVSHIPS Tech Manual.

HOW TO STUDY

The general methods of study are the same for everyone, but the real art entails discovery of the methods that are best for you. It is always best to study about a particular equipment while working on it. With a piece of equipment available, study the technical manual and relate the physical location and size of the component with it. On the job, learn by doing.

When studying theory or fundamentals of operation, always set up some plan of study. Study is a habit. It is best done under conditions and surroundings that do not distract. Learn in an orderly fashion so that the acquired bits of knowledge will serve as stepping stones in the process of learning. Read and study the material at hand with as much concentration as possible. Remember that electricity cannot be learned in a hurry. A consistent application of effort, however, brings a man to his goal sooner than he thinks.

BASIC RULES OF STUDY

The following rules of study will benefit those who find it difficult to learn and retain what they have read.

- Choose a comfortable, quiet, and well-lighted location. Read with pencil and paper handy for recording notes.

- Decide upon a portion of a chapter and the number of pages to be studied.

- Read quickly in order to get the main point of the subject.

- Reread carefully, then put the study material aside.

- List the main points, then check them with manual open.

- Reread the material more slowly. Try to remember the details and connection of each part.

- Write a detailed summary, using the manual only if necessary.

STUDYING THIS RATE TRAINING MANUAL

Before proceeding further in this Rate Training Manual, you should know its scope and purpose. Go over the table of contents and note the arrangement of topics. Subject matter can be organized and presented in many different ways. You will find it helpful to get an overall view of this manual's organization before starting to study. Here are some points of interest concerning this manual:

- It must be satisfactorily completed before you can advance to IC3 or IC2, whether you are in the Regular Navy or in the Naval Reserve.

- It is designed to provide information on the occupational qualifications for advancement to IC3 and IC2.

- The occupational qualifications that were used as a guide in the preparation of this manual were those promulgated in change 3 of the Manual of Qualifications for Advancement, NAVPERS 18068-C (June 1973). Changes in the IC Electrician's qualifications occurring after this edition of the Quals Manual became effective may not be reflected in the topics of this training manual.

- It includes subject matter that is related to both the KNOWLEDGE FACTORS and the PRACTICAL FACTORS of the qualifications for advancement to IC3 and IC2. No Rate Training Manual, however, can take the place of on-the-job experience for developing skill in the practical factors. When possible, this manual should be used in conjunction with the Record of Practical Factors, NAVPERS 1414/1.

- It is NOT designed to provide information on the military requirements for petty officers.

CHAPTER 2

SAFETY

The Secretary of the Navy, in establishing a Department of the Navy Safety Program, stressed, "Safety is an inherent responsibility of command..." He further outlined that "Assignment of safety responsibility at all echelons of command is a basic requirement." This means responsibility right down through second and third class petty officers. Most accidents which occur in noncombat operations can be prevented if all personnel cooperate in eliminating unsafe conditions and acts.

To assist shipboard personnel in carrying out their responsibilities concerning safety, the Chief of Naval Operations has issued the Shipboard Accident Prevention Manual, OPNAVINST 5101.2. In addition, safety information is issued periodically in various publications, pamphlets, and directives by commands, bureaus, and offices of the Navy Department. Also, the Naval Safety Center, Norfolk, Virginia, a portion of whose mission is to monitor safety in the fleet, obtains accident data from completed Accident/Near Accident Reports (3040 forms) and Accidental Injury/Death Reports (5100 forms) and from Safetygrams, which are submitted informally by ships. Publications issued by the Center of particular interest to forces afloat include FATHOM and Ships Safety Bulletin.

It is also your job as a petty officer to know and be able to perform the proper action when an accident does occur.

This chapter will cover some of the areas in which you as an IC man should exercise above-average caution. It will further give you some facts so that you can teach safety accurately and effectively. Finally, it will give the approved methods of action so that you will be able to rehearse your actions and thus be ready in the event of a casualty.

Instructions and procedures pertaining to safety aspects are contained in general and specific manuals such as Naval Ships Technical Manual. The safety precautions discussed in this chapter are not intended to replace those in various manuals. Safety precautions related to specific equipment are included at appropriate points throughout this training manual.

SAFETY REQUIREMENTS

All individuals have the responsibility to understand and observe safety standards and regulations which are established for the prevention of injury to themselves and other persons and damage to property and equipment. As a supervisor, you have the responsibility of setting a good example; you cannot ignore safety regulations and expect others to follow them.

EFFECTS OF ELECTRICITY

Because of the inherent danger of electrical shock, safety must rank as a prime concern to all IC men.

The factors that determine whether you receive a slight or fatal shock are (1) the amount and duration of current flow, (2) the parts of the body involved, and (3) the frequency of the current if it is A-C. Generally, the greater the current flow and the length of time one is subjected to it will determine the extent of the damage done. The Navy has also found that life or death may be determined by the nearness of the current path, through you, to vital nerve centers or organs. Frequency is also a determining factor, with 60 hertz current flow being slightly more dangerous than direct current.

The ability to resist an electrical shock varies from sailor to sailor and from day to day. However, NavShips has summarized the relationship of current magnitude to degree of shock as follows:

1. At about one milliamp (.001 ampere) shock is perceptible.
2. At about ten milliamp (.01 ampere) shock is sufficient to prevent voluntary control of the muscles.

Current Value	Effects
Less than 1 ma	No sensation.
1 to 20 ma	Mild sensation to painful shock, may lose control of adjacent muscles between 10 to 20 ma.
20 to 50 ma	Painful shock, severe muscular contractions, breathing difficult.
50 to 200 ma	Same as above, only more severe, up to 100 ma. A heart condition known as ventricular fibrillation may occur anywhere between 100 and 200 ma usually causing death almost immediately.
Over 200 ma	Severe burns and muscular contractions so severe that the chest muscles clamp the heart and stop it for the duration of the shock.

111.131

Table 2-1.—Sixty-Hertz Current Values Affecting Human Beings.

3. At about one hundred milliamp (.1 ampere) shock is usually fatal if it lasts for one second or more.

Table 2-1 may be an aid to you when you are instructing your strikers, as it points out the current values and their expected effects.

SAFE PRACTICES

When working on electrical or electronic circuits there are certain general precautions which must be observed. These precautions should be scrupulously followed by both yourself and the striker who is working with you.

(1) Remember that electrical and electronic circuits often have more than one source of power. Take time to study the schematics or wiring diagrams of the entire system to ensure that all power sources are deactivated.

(2) If pertinent, inform the remote station regarding the circuit on which work will be performed.

(3) Use one hand when turning switches on or off. Keep the doors to switch and fuse boxes closed, except when working inside or replacing fuses.

(4) After first making certain that the circuit is dead, use a fuse puller to remove cartridge fuses.

(5) All supply switches or cutout switches from which power could possibly be fed should be secured in the off or open (safety) position and tagged. The tag should read "THIS CIRCUIT WAS ORDERED OPEN FOR REPAIRS AND SHALL NOT BE CLOSED EXCEPT BY DIRECT ORDER OF (name and rank of person making, or directly in charge of repairs)," or "DANGER-SHOCK HAZARD—Do not change position of switch EXCEPT by direction of (name and rank of person making or directly in charge of repairs)."

(6) Keep clothing, hands, and feet dry if at all possible. When it is necessary to work in wet or damp locations, use a dry platform or wooden stool to sit or stand on, and place a rubber mat or other nonconductive material on top of the wood. Use insulated tools and insulated flashlights of the molded type when required to work on exposed parts. In all instances, repairs on energized circuits shall not be made with the primary power applied except in case of emergency, and then only after specific approval has been given by your supervisor, the chief IC electrician or electrical material officer. When approval has been obtained to work on equipment with the power applied, keep one hand free at all times (BEHIND YOU OR IN YOUR POCKET).

(7) Never short out, tamper with, or block open an interlock switch.

(8) Keep clear of exposed equipment; when it is necessary to work on it, work with one hand as much as possible.

(9) Avoid reaching into enclosures except when absolutely necessary; when reaching into an enclosure, use rubber blankets to prevent accidental contact with the enclosure.

(10) Make certain that equipment is properly grounded.

(11) Turn off the power before connecting alligator clips to any circuit.

(12) Never use your finger to test a "hot" line. Use approved meters or other indicating devices.

HIGH VOLTAGE PRECAUTIONS

Do NOT work with high voltage by yourself; have another person (safety observer), qualified in first aid for electrical shock, present at all times. The man stationed nearby should also know the circuits and location of the switches controlling the equipment, and should be given instructions to pull the switch immediately if anything unforeseen happens.

Remove all metal objects from your person. Always be aware of the nearness of high voltage lines or circuits. Use rubber gloves where applicable and stand on approved rubber matting. Not all so-called rubber mats are good insulators.

Always discharge the high voltage from components or terminals by using a safety probe similar to the one described later.

Do NOT hold the test probe when measuring circuits over 300 volts.

REPLACEMENT OF ELECTRON TUBES

Do NOT use bare hands to remove hot tubes from their sockets; use asbestos gloves or a tube puller.

Before replacing high voltage tubes, ensure that the plate (anode) cap or the lead terminal (on CRTs) has been properly discharged.

When replacing (or working close to) radioactive tubes, ensure that special precautions (discussed later) are observed.

GROUNDING OF POWER TOOLS AND EQUIPMENT

The possibility of electrical shock can be reduced by ensuring that all motor and generator frames, metal bases, and other structural parts of electrical and electronic equipment are at ground potential.

Normally, on steel-hull vessels, such grounds are inherently provided because the metal cases or frames of the equipment are in contact with one another and with the metal structure of the vessel. In some instances where such inherent grounding is not provided by the mounting arrangements, such as equipment supported on shock mounts, suitable ground connnections must be provided.

The conductors employed for this purpose generally are composed of flexible material (copper or aluminum) that provides sufficient current-carrying capacity to ensure an effective ground. In this manner, equipment cases and frames which are not intended to be above ground potential are effectively grounded, and the possibility of electrical shock to personnel coming in contact with metal parts of the equipment is minimized.

The secondary function of grounds is to improve the operation and continuity of service of certain electronic equipments. Faulty ground returns are detrimental to this function, and can result in intermodulation and noise voltage buildup, with associated service interruptions, false signals, equipment damage, or distortion as well as personnel hazard.

A satisfactory ground connection, regardless of the application, must meet certain requirements as contained in the General Specifications for Ships of the U. S. Navy, and the Naval Ships Technical Manual (NavShips 0901-960-0000 and 0901-967-0000, chapters 9600 and 9670). The characteristics of grounds are tested by the manufacturer of the equipment or by the naval development laboratories. Therefore, maintenance of ground conductors and connectors consists primarily of corrective and preventive maintenance.

In all instances where equipment grounding is provided, certain general precautions and preventive maintenance measures must be taken to ensure that all bonding surfaces (connection points or metallic junctions) are securely fastened and free of paint, grease, or other foreign matter that could interfere with the positive metal-to-metal contact at the ground connection point. A few of the precautions are:

(1) Periodically clean all strap-and-clamp type connectors to ensure that all direct metal-to-metal contacts are free from foreign matter.

(2) Check all mounting hardware for mechanical failure or loose connections.

(3) Replace any faulty, rusted, or otherwise unfit grounding strap, clamp, connection, or component between the equipment and the ground to the ship hull.

(4) When replacing a part of the ground connection, make certain that the metallic contact surfaces are clean, and that electrical continuity is reestablished.

(5) After the foregoing steps have been completed, recheck to be sure that the connection is securely fastened with the correct mounting hardware, and paint the ground strap and hardwater in accordance with current accepted procedures.

Because of the electrical shock hazards that could be encountered aboard ship, plugs and convenience outlets for use with portable test equipment and power tools normally are of the grounded type and are so designed that the plug must be rotated to the correct position before it can be inserted into the receptable. To ensure that the safety factors incorporated in these devices are in serviceable condition and are safe for use, the following precautions and inspections must be performed.

(1) Inspect the phenolic pin-guide insert of the receptacle to see that it is firmly in place and that the guide pin is not bent or damaged.

(2) Check the wiring terminals and connections of the plug. Loose connections and frayed wires on the plug surface must be corrected, and any foreign matter removed, before the plug is inserted into the receptacle.

(3) Do not attempt to insert a grounded type plug into a grounded receptacle without first aligning it properly. Always rotate the plug to such a position that its groove is aligned with the polarity pin inside the receptacle.

(4) Remember, NEVER USE A POWER TOOL OR A PIECE OF PORTABLE TEST EQUIPMENT UNLESS YOU ARE ABSOLUTELY SURE THAT IT IS PROPERLY GROUNDED.

RUBBER FLOOR MATTING

To eliminate likely causes of accidents and to afford maximum protection to personnel from the hazards associated with electrical shock, only the approved rubber floor matting for electrical and electronic spaces shall be used. In many instances after accidents have occurred, investigations showed that the operating locations and areas around electrical and electronic equipments have been provided with only general purpose black rubber floor matting. This type of matting should not be used because its electrical characteristics do not provide adequate insulating properties to protect personnel from the possibility of electric shock. In addition, the material used in the manufacture of this matting is not fire retardant.

For the protection of personnel when work is being performed on electricl or electronic equipments, steps should be taken to ensure that only the approved rubber floor matting (currently being specified by Military Specification MIL-M-15562) is used. The matting is a gray fire-retardant material with a diamond-shaped surface. Use of this matting will serve as a safety measure around electrical and electronic equipments where electrical potentials up to but not exceeding 3000 volts may be encountered. In addition, the matting will improve the general overall appearance of the interior communications spaces.

Careful design and fabrication of the floor matting material does reduce the possibility of accidents. However, to ensure that the safety factors that were incorporated in the manufacture of the material are effective, and the matting is completely safe for use, operation and maintenance personnel must make certain that all foreign substances that could possibly contaminate or impair the dielectric properties of the matting material are promptly removed from its surface areas. For this reason, a scheduled periodic visual inspection procedure and cleaning practice should be established. During the visual inspection procedure, personnel should make certain the dielectric properties of the matting have not been impaired or destroyed by oil impregnation, piercing by metal chips, cracking, or other defects. If it is apparent that the matting is defective for any reason, a replaceable section of matting material should be employed to cover the area affected.

SAFETY SHORTING PROBE

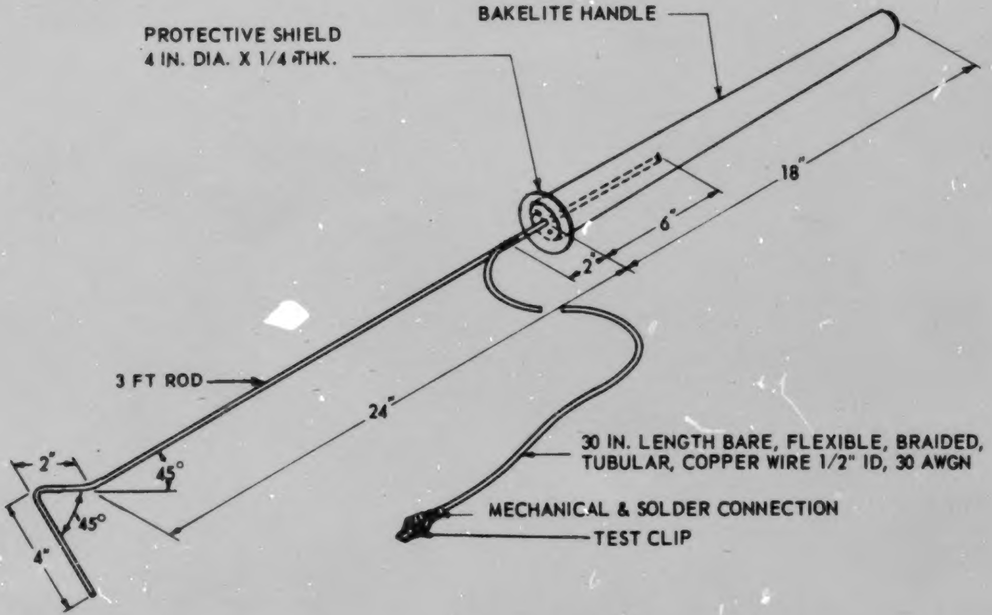
It is of the utmost importance that technical and maintenance personnel engaged in repairs of deenergized circuits which employ large capacitors use a safety shorting probe to discharge the circuits before performing any work on them.

Figure 2-1 illustrates and provides the necessary details for the fabrication of an approved safety shorting probe. It is possible that the dimensions given may not be suitable for all the various types of equipment located within a specific area; therefore, the length can best be determined by the requirement. However, materials used should be in conformance with or equivalent to those in the recommended list of materials required.

Construction details and the list of materials are self-explanatory; however, the following hints are included to help clarify any construction problems.

WARNING

Never reduce the length of the handle to the point where there will be less than 1 foot of clearance between the grip and the shorting rod.


BAKELITE HANDLE
PROTECTIVE SHIELD
4 IN. DIA. X 1/4 THK.
18"
6"
2"
3 FT ROD
24"
2"
45°
45°
4"
30 IN. LENGTH BARE, FLEXIBLE, BRAIDED,
TUBULAR, COPPER WIRE 1/2" ID, 30 AWGN
MECHANICAL & SOLDER CONNECTION
TEST CLIP

1.1(77C)

Figure 2-1.—Safety shorting probe.

Place the copper rod in a vise and bend the probe end in accordance with dimensions given in figure 2-1. Drill and tap the prescribed holes in the larger diameter end of the bakelite handle. Drill and tap the protective shield and attach it to the bakelite handle. Thread the unbent end of the copper rod and screw the rod into the bakelite handle. Attach one end of the ground wire to the copper rod, and attach the mesh-teeth clip at the other end of the ground wire. Copies of NavShips drawing, RE 10D 280 titled Safety Shorting Probe Fabrication Detail can be obtained from NavShips.

When using the safety shorting probe, always be sure first to connect the test clip to a good ground (if necessary, scrape the paint off of the grounding metal to make a good contact). Then hold the safety shorting probe by the handle and touch the probe end of the shorting rod to the point to be shorted out. The probe end is fashioned so that it can be hooked over the part or terminal to provide a constant connection by the weight of the handle alone. Always take care not to touch any of the metal parts of the safety shorting probe while touching the probe to the exposed "hot" terminal. It pays to be safe; use the safety shorting probe with care.

STEEL WOOL

It is a recognized fact that the use of steel wool for cleaning in IC equipment spaces is harmful to the operation of the equipment. A specific directive of Naval Ships Technical Manual, Chapter 9670, states; "Steel wool or emery in any form shall not be used on or near electronic equipment." In chapter 9650 of the same manual, comments on the maintenance of electronic contacts are as follows: "Emery paper or cloth or steel wool must never be used to clean contacts." The same paragraph then makes the following statements, indicating that steel wool particles are a menace: "Ventilation currents distribute them where they do the most harm." and "Magnetic materials, often being present, will collect ferrous particles."

Another publication which treats the harmful effects of using steel wool in electronic equipment spaces is the Naval Ship Systems Command Handbook of Cleaning Practices, NavShips 250342-1. Under the paragraph entitled Soil Removal from Aluminum, the handbook states: "The use of steel wool on electronic equipment is not permitted, since residual particles of steel may cause a short circuit." Additionally, further in the same handbook, the paragraph entitled Electrical Contacts, directs "clean with silver polish, fine sandpaper, or burnishing tools. Do not use emery or steel wool. Use vacuum to remove dust." Thus, the NavShips directives are clear and to the point: When cleaning electrical and electronic parts, DO NOT USE STEEL WOOL.

SOLDERING IRONS

When using a soldering iron, always bear in mind the following:

(a) In order to avoid burns, ALWAYS ASSUME that a soldering iron is hot.

(b) Never rest a heated iron anywhere but on a metal surface or rack provided for this purpose. Faulty action on your part could result in fire, extensive equipment damage, and serious injuries.

(c) Never use an excessive amount of solder, since drippings may cause serious skin or eye burns.

(d) Do not swing an iron to remove excess solder. Bits of hot solder that are removed in this manner can cause serious skin or eye burns, or bits of hot solder may ignite combustible material in the work area.

(e) When cleaning an iron, use a cleaning cloth but DO NOT hold the cleaning cloth in your hand. Always place the cloth on a suitable surface and wipe the iron across it to prevent burning your hand.

(f) Hold small soldering jobs with pliers or a suitable clamping device to avoid burns. Never hold the work in your hand.

(g) Do not use an iron that has a frayed cord or damaged plug.

(h) Do not solder components unless the equipment is disconnected from the power supply circuit. Serious burns or death can result from contact with a high voltage.

(i) After completing the task requiring the use of a soldering iron, disconnect the power cord from the receptacle and, when the iron has cooled off, stow it in its assigned storage area.

POWER TOOLS

The hazards associated with the use of portable power tools are electrical shock, bruises, cuts, particles in the eye, falls, and explosions. Safe practice in the use of these tools will reduce or eliminate such accidents. Listed below are some of the general safety precautions that you should observe when your work requires the use of portable power tools.

(a) Ensure that all metal-cased portable power tools are grounded.

(b) Do not use spliced cables.

(c) Inspect the cord and plug for proper connection. Do not use any tool that has a frayed cord or broken or damaged plug.

(d) Always connect the cord of a portable power tool into the extension cord before the extension cord is inserted into a live receptacle.

(e) Always unplug the extension cord from the receptacle before the cord of the portable power tool is unplugged from the extension cord.

(f) See that all cables are positioned so that they will not constitute a tripping hazard.

(g) Wear eye protection when orking where particles may strike the eyes.

(h) After completing the task requiring the use of a portable power tool, disconnect the power cord as described in step (e) and stow the tool in its assigned location.

HANDTOOLS

For your safety, certain precautions should be taken when working with handtools. Normally, there should be no problems when working with these tools, but there are certain conditions under which they may constitute a danger to you. Listed below are some of the dangers and safety precautions to be considered when using handtools.

(a) One source of danger that often is neglected or ignored is the use of handtools which are no longer considered serviceable. Tools having plastic or wooden handles that are cracked, chipped, splintered, or broken may result in injuries to personnel from cuts, bruises, particles striking the eye, and the like. Such tools should be condemned, replaced, or, if at all possible, repaired, before they cause accidents.

(b) Another source of danger that often is neglected or ignored is the unsafe work practice of covering the metal handle of a tool with a layer of friction tape or with a cambric sleeving to form an improvised insulated tool. This practice does not afford an adequate insulating barrier to protect personnel from dangerous voltages; therefore, steps should be taken to ensure that this unsafe practice is discontinued immediately.

(c) When it is necessary (in an emergency only) to improvise an insulating barrier between the tool and the individual's hand, the approved method is first to apply several layers of approved rubber insulating tape on the metal surface areas to be covered, and then to apply a layer or two of friction tape over the insulation material. In this manner, an adequate insulating barrier is provided, and the possibility of accidental contact with a lethal voltage is minimized.

AEROSOL DISPENSERS

Deviation from prescribed procedures on the part of IC men in the selection, application, storage, or disposal of aerosol dispensers containing industrial sprays has resulted in serious injury to personnel because of toxic effects, fire, and explosion. Specific instructions concerning the precautions and procedures that must be observed to prevent physical injury cannot be given because there are so many types of industrial sprays available. However, all personnel concerned with the handling of aerosol dispensers containing volatile substances should clearly understand the hazards involved and the need to use all protective measures required to prevent personal injury. Strict compliance with the instructions printed on the aerosol dispenser will prevent many of the accidents which result from misapplication, mishandling, or improper storage of industrial sprays used in the Naval service for electrical and electronic equipment.

Basic rules which must be observed by operating and maintenance personnel in order to ensure safety in the use of aerosol dispensers are:

(a) Carefully read and comply with the instructions printed on the can.

(b) Do not use any dispenser that is capable of producing dangerous gases or other toxic effects in an enclosed area unless the area is adequately ventilated.

(c) If a protective coating must be sprayed in a space which lacks adequate ventilation, an air respirator, self-contained breathing apparatus, or preferably, fresh air supplied from outside the enclosure by use of portable blowers or exhaust fans should be provided. Such equipment will prevent inhalation of toxic vapors.

(d) Do not spray protective coatings on warm or energized equipment, because to do so creates a fire or toxic gas hazard.

(e) Prevent all contact to the skin with the liquid contained in the dispenser. Contact with some of the liquids being used may result in burns, while milder exposures may cause rashes.

(f) Do not puncture the dispenser. It is pressurized; therefore, injury can result from this practice.

(g) Do not discard used dispensers in wastebaskets that are to be emptied into an incinerator, or an explosion of the dispenser case may result.

(h) Keep dispensers away from direct sunlight, heaters, and other sources of heat.

(i) Do not store dispensers in an environment where the temperature is above the temperature limits printed on the dispenser case. Exposure to high temperature may cause bursting of the container.

BUILT-IN SAFETY DEVICES

Many modern equipments are provided with built-in safety devices (interlock switches and such) to prevent technical and maintenance personnel from coming into contact with electrical potentials in excess of 50 volts RMS, However, some of these protective devices are removed or destroyed by personnel who tamper with, block open, or otherwise "override" the safety devices. The foregoing practices are actions which MUST NOT BE PERFORMED. They are practices that could lead to personal injury or death.

After an accident has occurred, investigation almost always shows that it could have been prevented by following established safety precautions and procedures. Among these are the following:

(a) Do not troubleshoot a circuit with the primary power applied. This includes the aforementioned unsafe practice of "overriding" the equipment's built-in safety devices.

(b) Carefully study the schematic and wiring diagrams of the entire circuit, noting which circuits must be deenergized in addition to the main power supply.

(c) Obtain permission from your supervisor if it becomes necessary to work on energized equipment.

(d) If approval is given to work on equipment with the power applied, never work alone; always have an assistant who can provide or get help in an emergency.

(e) When making measurements or tests, always keep one hand behind your back or in your pocket.

(f) Do not reach into the equipment enclosure unless absolutely necessary; when this must be done, make sure that approved insulating material and procedures are used(stand on a rubber matting, wear rubber gloves).

Because of the hazards which confront IC Electricians in the performance of their duties, each man concerned should make it his responsibility to read and thoroughly understand the safety practices and procedures contained in applicable plublications before attempting to make repairs or adjustments on the equipment. He should never endanger his life or the lives of his associates by disregarding or taking too lightly the built-in devices that are provided for his safety.

RADIOACTIVE ELECTRON TUBES

Electron tubes containing radioactive material are now commonly used. These tubes are known as TR, ATR, PRE-TR, spark-gap, voltage-regulator, gas-switching, and cold-cathode gas-rectifier tubes. Some of these tubes contain radioactive material and have intensity levels which are dangerous; they are so marked in accordance with Military Specifications. The majority of these tubes contain radioactive cobalt (Co-60), radium (Ra-226), or carbon (C-114); several contain nickel (Ni-63); and a relative few contain cesium-barium (Cs Ba-137).

So long as the electron tube containing any of the previously listed radioactive material remains intact and is not broken, no great hazard exists. However, if the tube is broken and the radioactive material is exposed, or escapes from the confines of the electron tube, the radioactive material becomes a potential hazard. The concentration of radioactivity in a normal collection of electron tubes at a maintenance shop does not approach a dangerous level, and the hazards of injury from exposure are slight. However, at major supply points, the storage of large quantities of radioactive electron tubes in a relatively small area may create a hazard. For this reason, personnel working with equipments employing electron tubes containing radioactive material, or in areas where a large quantity of radioactive tubes is stored, should read and become thoroughly familiar with the safety practices promulgated in shipboard instructions.

Hints pertaining to proper handling of radioactive tubes, precautions to ensure personnel safety, and a list of tubes containing radioactive material are provided herein. The following precautions should be taken to ensure proper handling of radioactive electron tubes and to ensure safety of personnel.

Radioactive tubes should not be removed from cartons until immediately prior to actual installation.

When a tube containing a radioactive material is removed from an equipment, it should be placed in an appropriate carton to prevent possible breakage.

A radioactive tube should never be carried in your pocket, or elsewhere about you in such a manner that breakage can occur.

If breakage does occur during handling or removing of a radioactive electron tube, notify the cognizant authority and obtain the services of qualified radiological personnel immediately.

Isolate the immediate area of exposure to prevent other personnel from possible contamination and exposure.

Do not permit contaminated material to come in contact with any part of your body.

Take care to avoid breathing any vapor or dust which may be released by tube breakage.

Wear rubber or plastic gloves at all times during cleanup and decontamination procedures.

Use forceps for the removal of large fragments of a broken radioactive tube. The remaining small particles can be removed with a vacuum cleaner, using an approved disposal collection bag. If a vacuum cleaner is not available, use a wet cloth to wipe the affected area. In this case, be sure to make one stroke at a time. DO NOT use a back-and-forth motion. After each stroke, fold the cloth in half, always holding one clean side and using the other for the new stroke. Dispose of the cloth in the manner stated later.

No food or drink should be brought into the contaminated area or near any radioactive material.

Immediately after leaving a contaminated area, personnel who have handled radioactive material in any way should remove any clothing found to be contaminated. They should also thoroughly wash their hands and arms with soap and water, and rinse with clean water.

Immediately notify a medical officer if a personnel wound is sustained from a sharp radioactive object. If a medical officer cannot reach the scene immediately, mild bleeding should be stimulated by pressure about the wound and the use of suction bulbs. DO NOT USE THE MOUTH.

If the wound is of the puncture type, or the opening is small, make an incision to promote free bleeding, and to facilitate cleaning and flushing of the wound.

When cleaning a contaminated area, seal all debris, cleaning cloths, and collection bags in a container such as a plastic bag, heavy wax paper, or glass jar, and place in a steel can until disposed of in accordance with existing instruction.

Decontaminate all tools and implements used to remove a radioactive substance, using soap and water. Monitor the tools and implements for radiation with an AN/PDR-27(); they should emit less than 0.1 MR/HR at the surface.

CLEANING SOLVENTS

IC men who smoke while using a volatile cleaning solvent are inviting disaster. Unfortunately, many such disasters have occurred. For this reason, the Navy does not permit the use of gasoline, benzine, ether, or like substances for cleaning solvent purposes. Only nonvolatile solvents should be used to clean electrical or electronic apparatus.

In addition to the potential hazard of accidental fires, many cleaning solvents are capable of damaging the human respiratory system in cases of prolonged inhalation. The following list of "DO NOTs" will serve as effective reminders to men who must use cleaning solvents.

1. DO NOT work alone or in a poorly ventilated compartment.
2. DO NOT use carbon tetrachloride. This is a highly toxic compound.
3. DO NOT breathe directly the vapor of any cleaning solvent for a long time.
4. DO NOT spray cleaning solvents on electrical windings or insulation.
5. DO NOT apply solvents to warm or hot equipment, since this increases the toxicity hazard.

The following reminders are positive safety steps to be taken when cleaning operations are underway.

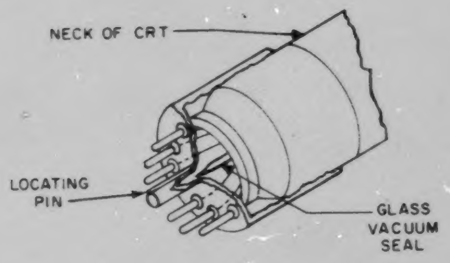
1. Use a blower or canvas wind chute to blow air into a compartment in which a cleaning solvent is being used.
2. Open all usable portholes, and place wind scoops in them.
3. Place a fire extinguisher close by, ready for use.
4. Use water compounds in lieu of other solvents where feasible.
5. Wear rubber gloves to prevent direct contact.
6. Use goggles when a solvent is being sprayed on surfaces.
7. Hold the nozzle close to the object being sprayed.

Inhibited methyl chloroform (1, 1, 1, Trichloroethane) should be used only where water compounds are not feasible. Methyl chloroform has a threshold of 500 parts-per-million (PPM) in air. The threshold is the point above which the concentration in air becomes dangerous. Methyl chloroform is toxic and should be used with care as concentrations of the vapor are anesthetic and can be fatal. Care requires plenty of ventilation and observance of fire precautions. Avoid direct inhalation of the vapor. Inhibited methyl chloroform is not safe for use with a gas mask, since the vapor displaces oxygen in the air.

CATHODE-RAY TUBES (CRTs)

Cathode-ray tubes should always be handled with extreme caution. The glass envelope encloses a high vacuum and, because of its large surface area, is subject to considerable force caused by atmospheric pressure. (The total force on the surface of a 10-inch CRT is 3750 pounds, or nearly two tons; over 1000 pounds is exerted on its face alone.) Proper handling and disposal instructions for CRTs are as follows:

1. Avoid scratching or striking the surface.
2. Do not use excessive force when removing or replacing the CRT in its deflection yoke or its socket.
3. Do not try to remove an electromagnetic type CRT from its yoke until you make sure that the high voltage has been discharged from its anode connector (hole).
4. Never hold the CRT by its neck.
5. Always set a CRT with its face down on a thick piece of felt, rubber, or smooth cloth.
6. Always handle the CRT gently. Rough handling or a sharp blow on the service bench can displace the electrodes within the tube, causing faulty operation.



20.320(40)
Figure 2-2.—Cathode-ray tube base structure.

Before a CRT is discarded, it should be made harmless by breaking the vacuum glass seal. To accomplish this, proceed as follows:

1. Place the tube that is to be discarded in an empty carton, with its face down.
2. Carefully break off the locating pin from its base (fig. 2-2).

WARNING

The chemical phosphor coating of the CRT face is extremely toxic. When disposing of a broken tube, be careful not to come into contact with this compound.

An alternate method of rendering a CRT harmless is to place it in a carton. Then, using a long, thin rod, pierce through the carton and the side of the CRT.

ELECTRICAL FIRES

The three general classes of fires are A, B, and C. Class A fires involve wood, paper, cotton and wool fabrics rubbish, and the like. Class B fires involve oil, grease, gasoline and aircraft fuels, paints, and oil-soaked materials. Class C fires involve insulation and other combustible materials in electrical and electronic equipment.

Fire is not only a hazard to personnel safety, but may result in damage to or loss of equipment. Fuel (a combustible substance), oxygen (air), and sufficient heat to vaporize the fuel must be present simultaneously to ignite a fire. When a substance burns, however, it is the vapor of the substance combined with oxygen that burns and not the actual substance in its solid or liquid form. Fire can be controlled and/or extinquished by eliminating or controlling either fuel, oxygen, or heat. If the oxygen can be diluted or prevented from coming into contact with the substance, or if the heat can be reduced by cooling the fuel to a temperature below that at which it ignites, the fire will be extinguished. In an electrical fire, it is not very likely that the fuel (a combustible substance) can be removed from the oxygen and heat; therefore, to extinguish the fire, either the heat or oxygen, or both, must be controlled or removed.

Electrical or electronic equipment fires result from overheating, short circuits (parts failure), friction (static electricity), or radio-frequency arcs. Also, an equipment may be ignited by exposure to nearby Class A or B fires. Since Class C fires involve electrical circuits, electrical shock is an added dangerous and hazardous condition. Thus, whenever possible, any electrical equipments exposed to a Class A or Class B fire, or actually ignited by such a fire, should be deenergized immediately. If the equipment cannot be deenergized completely, protective measures must be enforced to guard against electrical shock. In addition, extinguishing agents other than gases will contaminate delicate instruments, contacts and similar electrical devices. Therefore, carbon dioxide (CO_2) is the preferred extinguishing agent for electrical fires because it does not conduct electricity and is a protective measure against shock; also, there is much less likelihood of equipment damage.

A dry chemical type of extinguishing agent, composed chiefly of sodium bicarbonate, is suitable for electrical fires because it also is a nonconductor and, therefore, protects against electrical shock. However, damage to electrical or electronic parts may result from the use of this agent. The dry chemical extinguisher is similar in appearance to the CO_2 extinguisher.

A SOLID STREAM OF WATER MUST NEVER BE USED TO EXTINGUISH ELECTRICAL FIRES IN ENERGIZED EQUIPMENT because water usually contains minerals which make it conductive; the conductivity of sea water is many times greater than that of fresh water. If circumstances warrant the use of fresh or sea water, fog produced by a special hose nozzle (fog head or tip) may be used in electrical or electronic equipments spaces. However, even though the fog is a fine diffusion or mist of water particles with very little conductivity, there is still some danger of electric shock, unless the equipment is completely deenergized. Also, fog condensation on electrical equipment frequently damages the components, and this damage must be corrected after the fire. The nozzle should never be removed from the end of the hose since the water pressure at the fireplug may be upwards to 100 PSI. If this is done, a dangerous whip-lash action of the hose may result and cause injury to yourself or nearby personnel.

Foam is not recommended for electrical fires because of equipment damage and the possible shock hazard to personnel; however, if required, foam should be used only on DE-ENERGIZED circuits. When a blanket of foam is applied to a burning substance, the foam smothers the fire; that is, it cuts off the air supply to the burning substance. Thus, the supply of oxygen necessary to support combustion is isolated from the substance, and the fire will be extinguished.

METHODS OF FIREFIGHTING

The three methods of firefighting, that is, the removal of fuel, the removal of heat, or the control of air (oxygen), are described in the following paragraphs.

Removal of Fuel

When fighting a fire, remove any combustible materials (fuel) from the area to prevent their coming in contact with the fire. In an electrical fire, this is done primarily to prevent the fire from spreading. Since it is not very practical to remove combustible substances from the source of fire within electrical or electronic equipment, either the removal of heat or the control of air (or both) is the most practical approach in combatting an electrical fire.

Removal of Heat

Heat is transmitted by radiation, conduction, and convection. In radiation, heat radiates in all directions from the fire, thus raising the temperature of nearby substances or materials. In conduction, heat is transmitted through a substance by contact with fire, which, in turn, gives off heat along the length and mass of the substance, such as along metal work benches or through compartment or cabinet walls. In convection, heated air and gases rise from a fire to contact and transfer heat to other substances or materials nearby. Water fog and water can be used only to remove heat from the substances or materials surrounding an electrical fire; however, carbon dioxide must be used as the extinguishing agent on the actual electrical fire.

Control of Air (Oxygen)

Air, which is composed of approximately 21 percent oxygen and 79 percent nitrogen and other gases, is difficult to control in most cases because it is impossible to remove air from the atmosphere surrounding the fire. However, the air can be diluted with noncombustible gases which will reduce the oxygen content. The atmospheric oxygen content reduction will, in turn, extinguish the fire. The oxygen must be diluted to a certain saturation point before the fire is extinguished. Thus, sufficient carbon dioxide must be added to the atmosphere to lower the percentage of the oxygen ontent to the saturation point which will not support the combustion of the substance involved.

Carbon dioxide, a noncorrosive gas, is one and one-half times heavier than air and thus remains close to the surface of the deck or floor. It cannot be seen or smelled; its presence gives no evidence that can be recognized by the senses. When used, this gas flows down and over the fire to smother it. However, the very qualities which make carbon dioxide a valuable extinguishing agent also make it dangerous to life; when carbon dioxide dilutes and replaces the oxygen in the air to the extent that combustion cannot be sustained, respiration cannot be sustained either. Personnel should be aware that prolonged exposure to an atmosphere heavily laden with carbon dioxide will cause suffocation unless special breathing apparatus is used. Personnel suffering from prolonged exposure to carbon dioxide must be administered artificial respiration and oxygen, and must be kept warm and quiet. Personnel using the carbon dioxide fire extinguisher must also be aware of the fact that the "snow" discharge from the extinguisher blisters the skin and causes painful "burns" if it is allowed to contact and remain on the skin. The cooling effect of this gas upon the fire is slight, notwithstanding its low temperature resulting from rapid expansion as it leaves the fire extinguisher cylinder.

When carbon dioxide is properly directed and applied to a Class C fire, there is no danger of an electrical shock (since carbon dioxide is a nonconductor of electricity). However, if the discharge horn of a portable carbon dioxide extinguisher collects ice and the horn is allowed to accidentally touch an energized circuit, the horn may transmit a shock to the person handling the extinguisher.

Most portable CO_2 extinguishers have a locking pin that must be removed in order to operate the release valve. It is imperative that the user check to be sure that this pin is removed before deciding that he has an inoperative extinguisher. Once the pin is removed, the squeeze-grip type release valve extinguisher is operated by a simple "squeeze grip" of the handle; the older CO_2 extinguisher having a disk type release valve is operated by turning a small wheel. Once opened (the release valve sealing disk ruptured) the disk type valve cannot be closed to hold the unexpended gas indefinitely; the entire charge will eventually leak out requiring that the cylinder be refilled and a new sealing disk be inserted in the release valve. On the other hand, the squeeze-grip type valve makes a gastight seal when pressure on the "squeeze-grip" is released; it can be opened and closed repeatedly without loss of gas from leakage.

The following general procedure is used for fighting an electrical fire:

1. Promptly deenergize the circuit or equipment affected. Shift the operation to standby circuit or equipment, if possible.
2. Sound an alarm in accordance with station regulations or the ship's fire bill. When ashore, notify the fire department; if afloat, notify the Officer of the Deck. Give the fire location and state what is burning. If possible, report the extent of the fire, that is, what its effects are upon the surrounding area.
3. Secure ventilation by closing compartment air vents or windows.
4. Attack the fire with portable CO_2 extinguishers (or a CO_2 hose reel system, if available) as follows:
    a. Remove the locking pin from the release valve.
    b. Grasp the horn handle by the insulation (thermal) grip; the grip is insulated against possible hand frostbite.
    c. Squeeze the release lever (or turn the wheel) to open the valve and thus release the carbon dioxide; at the same time, direct the discharge flow of the carbon dioxide toward the base of the fire.
    d. Aim and move the horn of the extinguisher slowly from side to side.
    e. Do not stop the discharge from the extinguisher too soon. When the fire has been extinguished, coat the critical surface areas involved with carbon dioxide "snow" in order to cool the substances (fuels) involved and prevent a rekindling of the fire.

5. Avoid prolonged exposure to high concentrations of carbon dioxide in confined spaces since there is danger of suffocation unless special breathing apparatus is available.

6. Administer artificial respiration and oxygen to any personnel overcome by carbon dioxide fumes and keep the patient warm.

Fire aboard a Navy vessel at sea under normal conditions sometimes is more fatal and damaging to both personnel and the ship itself, than that resulting from battle. It is extremely important for all personnel to know and understand the danger of fires. Part of this knowledge is to know the type and location of all firefighting equipment and apparatus in the immediate working and berthing spaces, and throughout the ship. It is too late to get this knowledge after a fire is started; the time is now.

FIRE EXTINGUISHERS

In addition to the aforementioned fire precautions, fire extinguishers of proper type must be conveniently located near all places that are exposed to constant fire danger, especially places near high-voltage equipment. Table 2-2 lists the types of fire extinguishers that are normally available for use.

ELECTRIC SHOCK

In the case of severe electric shock, the victim is usually very white or blue. His pulse is extremely weak or entirely absent, and unconciousness is complete. Burns are usually present. The victim's body may become rigid or stiff in a few minutes. This condition can be caused by muscular reaction, and is not necessarily to be considered as rigor mortis. Therefore, artificial respiration is necessary, regardless of body stiffness, as recovery has been reported in such cases. The ordinary general test for death, or the appearance of rigor mortis should not be accepted as valid.

RESCUE OF VICTIMS

The rescue of electric shock victims is dependent upon prompt first aid.

EXTINGUISHER	USE
CO_2 Gas	Effective on any type fire, particularly electrical fires.
Soda-Acid	Effective only on Class A fires. Not recommended for electrical fires as compound is good conductor of electricity. Not effective on burning compounds, such as oil and the like.
Foam	Very effective on burning compounds, such as oil and similar materials. Not satisfactory for electrical fires, as compound is a good conductor of electricity.

140.114
Table 2-2.—Types of Fire Extinguishers.

WARNING

DO NOT attempt to administer first aid or come in physical contact with an electric shock victim before the victim has been removed from the live conductor.

When attempting to administer first aid to an electric shock victim, proceed as follows.

1. Shut off the high voltage.

2. If the high voltage cannot be deactivated, remove the victim immediately, observing the following precautions;

a. Protect yourself with dry insulating material.

b. Use a dry board, belt, dry clothing, or other available nonconductive material to free the victim from the live wire, DO NOT TOUCH the victim.

c. After removal of the victim from the live conductor, proceed with the administration of artificial respiration as described below.

RESUSCITATION AND ARTIFICIAL RESPIRATION

Resuscitation for electric shock. NOTE: The following instructions on resuscitation were furnished by the Bureau of Medicine and Surgery.

Artificial resuscitation, after electric shock, includes artificial respiration to reestablish breathing, and external heart massage to reestablish heart beat and blood circulation (fig. 2-3).

To aid a victim of electric shock after removing him from contact with the electricity, immediately apply mouth-to-mouth artificial respiration.

If there is no pulse, immediately apply heart massage. Don't waste precious seconds carrying the victim from a cramped, wet, or isolated location to a roomier, dryer, frequented location. If desired, breathe into victim's mouth through a cloth or a handkerchief placed over his face. If assistance is available, take turns breathing into victim and in massaging his heart (fig. 2-3 A, B, C).

Cardiac Arrest (Loss of Heartbeat)

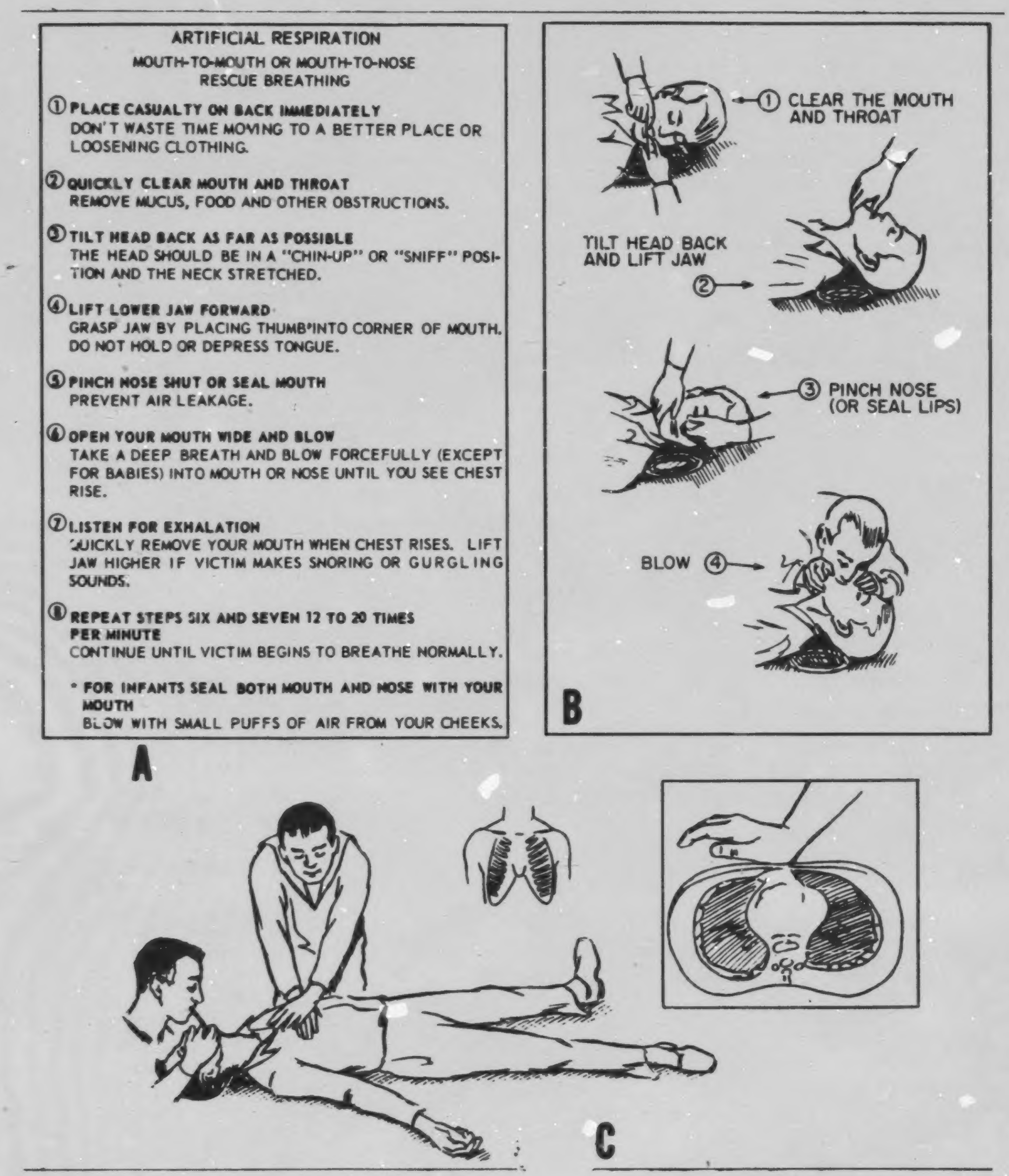
If the subject has suffered an electric shock and has no heartbeat, he has a cardiac arrest. This is demonstrated by finding a complete absence of any pulse at the wrist or in the neck. Associated with this the pupils of the eye will be dilated, and respiration will be weak or stopped. The subject may appear to be dead. Under these circumstances, severe brain damage will occur in four minutes unless circulation is reestablished by cardiac massage.

Closed Chest Cardiac Massage.

This method has been adopted as practical and can be administered by anyone who is properly instructed. The object in closed chest cardiac massage is to squeeze the heart through the chest wall, thereby emptying it to create a peripheral pulse. This must be done about 60 times each minute.

Place the subject on his back; a firm surface, such as the deck, is preferred. Expose subject's chest.

Kneel beside victim; feel for lower end of subject's sternum (breastbone); place one hand across breastbone so heel of hand covers the lower part; place second hand on top of the



ARTIFICIAL RESPIRATION

MOUTH-TO-MOUTH OR MOUTH-TO-NOSE
RESCUE BREATHING

① **PLACE CASUALTY ON BACK IMMEDIATELY**
DON'T WASTE TIME MOVING TO A BETTER PLACE OR LOOSENING CLOTHING.

② **QUICKLY CLEAR MOUTH AND THROAT**
REMOVE MUCUS, FOOD AND OTHER OBSTRUCTIONS.

③ **TILT HEAD BACK AS FAR AS POSSIBLE**
THE HEAD SHOULD BE IN A "CHIN-UP" OR "SNIFF" POSITION AND THE NECK STRETCHED.

④ **LIFT LOWER JAW FORWARD**
GRASP JAW BY PLACING THUMB INTO CORNER OF MOUTH. DO NOT HOLD OR DEPRESS TONGUE.

⑤ **PINCH NOSE SHUT OR SEAL MOUTH**
PREVENT AIR LEAKAGE.

⑥ **OPEN YOUR MOUTH WIDE AND BLOW**
TAKE A DEEP BREATH AND BLOW FORCEFULLY (EXCEPT FOR BABIES) INTO MOUTH OR NOSE UNTIL YOU SEE CHEST RISE.

⑦ **LISTEN FOR EXHALATION**
QUICKLY REMOVE YOUR MOUTH WHEN CHEST RISES. LIFT JAW HIGHER IF VICTIM MAKES SNORING OR GURGLING SOUNDS.

⑧ **REPEAT STEPS SIX AND SEVEN 12 TO 20 TIMES PER MINUTE**
CONTINUE UNTIL VICTIM BEGINS TO BREATHE NORMALLY.

* **FOR INFANTS SEAL BOTH MOUTH AND NOSE WITH YOUR MOUTH**
BLOW WITH SMALL PUFFS OF AIR FROM YOUR CHEEKS.

A
① CLEAR THE MOUTH AND THROAT
TILT HEAD BACK AND LIFT JAW
②
③ PINCH NOSE (OR SEAL LIPS)
BLOW ④
B
C

4.224

Figure 2-3.—Artificial respiration and cardiac massage.

first so that the fingers point toward neck as in figure 2-3 C.

With arms nearly straight, rock forward so that a controlled amount of your body weight is transmitted through your arms and hands to the breastbone. The amount of pressure to apply will vary with the subject. It should be applied as smoothly as possible. With an adult subject, the chest wall should be depressed 2 to 3 inches with each pressure application.

Repeat application of pressure about 60 to 80 times per minute.

An assistant should be ventilating the subject's lungs preferably with pure oxygen under intermittent positive pressure; otherwise with mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone, you must concentrate on the massage until help can arrive.

Direct other assistants, when available, to keep checking the patient's pulse. Use the least pressure that will secure an effective pulse beat. The pupils will become smaller when effective cardiac massage is being performed.

Pause occasionally to determine if a spontaneous heartbeat has returned.

PRECAUTIONS: Make every effort to keep the hands positioned as described in order to prevent injuries to the liver, ribs, or other vital organs. Since the heart cannot recover unless supplied with oxygen blood, it is necessary to accompany cardiac massage with mouth-to-mouth artificial respiration. When there is only one operator, the cardiac massage must be interrupted every half-minute or so to institute rapid mouth-to-mouth breathing for three or four respirations.

The mouth-to-mouth (or mouth-to-nose) technique of artificial respiration is the most effective of the resuscitation techniques.

The mouth-to-mouth (or mouth-to-nose) technique of artificial respirations is the most practical method for emergency ventilation of an individual of any age who has stopped breathing, in the absence of equipment or of help from a second person, regardless of the cause of cessation of breathing.

Persons who are trained in first-aid do not usually have the experience, training, and essential equipment to determine whether or not lack of breathing is a result of disease or accident. Therefore, some form of artificial respiration should be started at the earliest possible moment.

Any procedure that will obtain and maintain an open air passageway from the lungs to the mouth and provide for an alternate increase and decrease in the size of the chest, internally or externally, will move air in and out of a non-breathing person.

The mouth-to-mouth or (mouth-to-nose) technique has the advantage of providing pressure to inflate the victim's lungs immediately. It also enables the rescuer to obtain more accurate information on the volume, pressure, and timing of efforts needed to inflate the victim's lungs than are afforded by other methods.

When a person is unconscious and not breathing, the base of the tongue tends to press against and block the upper air passageway. The procedures described below should provide for an open air passageway when a lone rescuer must perform artificial respiration.

First, if there is foreign matter visible in the mouth, wipe it out quickly with your finger or a cloth wrapped around your finger. Tilt the head back so the chin is pointed upward (fig. 2-4A). Pull or push the jaw into a juttingout position (fig. 2-4B and C). These maneuvers should relieve obstruction of the airway by moving the base of the tongue away from the back of the throat.

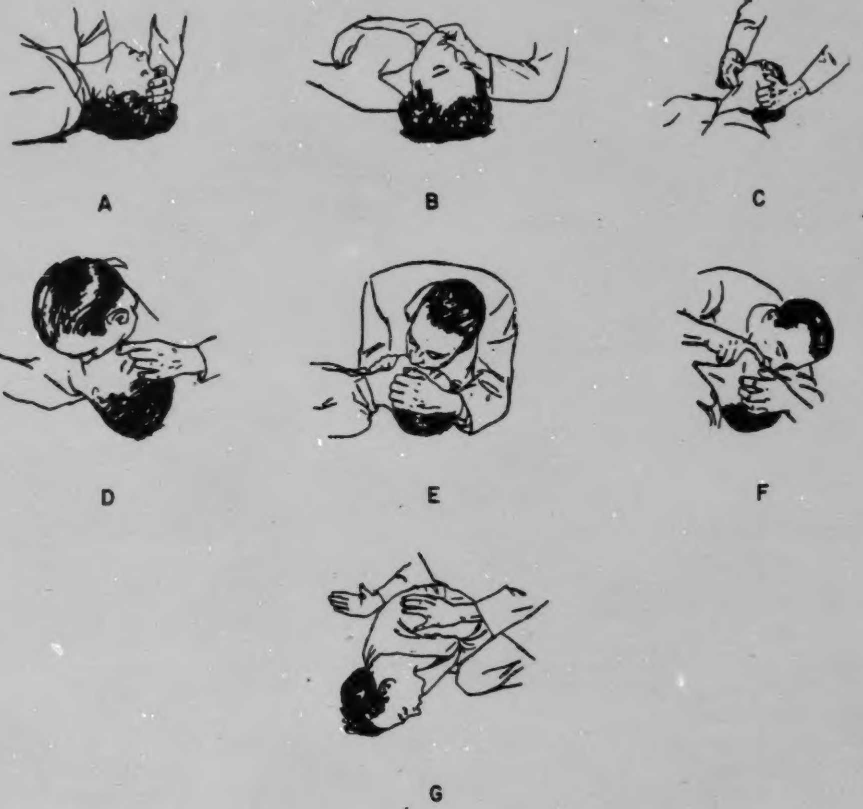
Open your mouth wide and place it tightly over the victim's mouth. At the same time pinch the victim's nostrils shut (fig. 2-4D) or close the nostrils with your cheek (fig. 2-4E). You may close the victim's mouth and place your mouth over the nose (fig. 2-4F).

Blow into the victim's mouth or nose. Air may be blown through the victim's teeth, even though they may be clenched. The first blowing efforts should determine whether or not obstruction exists.

Remove your mouth, turn your head to the side, and listen for the return rush of air that indicates air exchange. Repeat the blowing effort. Blow vigorously at the rate of about 12 breaths per minute.

If you are not getting air exchange, recheck the head and jaw position. If you still do not get air exchange, quickly turn the victim on his side and administer several sharp blows between the shoulder blades in the hope of dislodging foreign matter (fig. 2-4G).

Again sweep your finger through the victim's mouth to remove foreign matter. Those who do not wish to come into contact with the person may hold a cloth over the victim's mouth or nose and breathe through it. The cloth does not greatly affect the exchange of air.



4.224

Figure 2-4. —Mouth-to-mouth respiration.

WORKING ALOFT

When radio or radar antennas are energized by transmitters, workmen must not go aloft unless advance tests show positively that no danger exists. A casualty can occur from even a small spark drawn from a charged piece of metal or rigging. Although the spark itself may be harmless, the "surprise" may cause the man to let go his grasp involuntarily. There is also shock hazard if nearby antennas are energized, such as those on stations ashore or aboard a ship moored alongside or across a pier.

Danger also exists that radar or other rotating antennas might cause men working aloft to fall by knocking them from their perch. Motor safety switches controlling the motion of radar antennas must be tagged and locked open before anyone is allowed aloft close to such antennas.

If you work near a stack, draw and wear the recommended oxygen breathing apparatus. Among other toxic substances, stack gas contains carbon monoxide. Carbon monoxide is too unstable to build up to a high concentration in the open, but prolonged exposure to even small quantities is dangerous.

Observe these safety precautions when you are going aloft:

1. You must have permission of the Communications Watch Officer and OOD.
2. You must have the assistance of another man along with a ship's Boatswain's Mate qualified in rigging.
3. Wear a safety belt. To be of any benefit, the belt must be fastened securely as soon as you reach the place where you will work. Some men have complained on occasion that a belt is clumsy

and interferes with movement. It is true the job may take a few minutes longer, but it is also true that a fall from the vicinity of an antenna is usually fatal.

4. Do not attempt to climb loaded with tools. Keep both hands free for climbing. Tools can be raised to you by your assistant below. Tools should be secured with preventer lines to avoid dropping them on your shipmate.

5. Ensure yourself of good footing and grasp at all times.

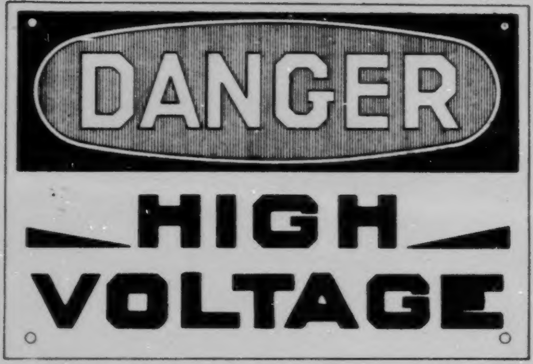
6. Remember the nautical expression of old seafarers: HOLD FAST

7. Ensure that the boiler safety valves are not being set by checking with the engineer officer.

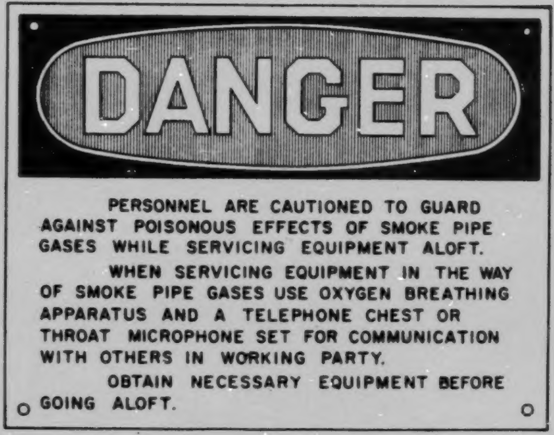
WARNING SIGNS, PLATES, AND TAGS

Warning signs and suitable guards shall be provided to prevent personnel from coming into accidental contact with dangerous voltages, for warning personnel of possible presence of explosive vapors, for warning personnel working aloft of poisonous effects of stack gases, and for warning of other dangers which may cause injuries to personnel. Equipment installation should not be considered completed until assurance has been posted in full view of operating personnel.

Certain types of standard electronics warning signs are available for procurement for the Commander, Philadelphia Naval Shipyard. A list of signs that are available has been distributed to all ships, commands, and shore activities. Any warning signs not listed should be ordered on a separate requesting document.



40.67(31)
Figure 2-5. —High voltage warning sign.



PERSONNEL ARE CAUTIONED TO GUARD AGAINST POISONOUS EFFECTS OF SMOKE PIPE GASES WHILE SERVICING EQUIPMENT ALOFT.

WHEN SERVICING EQUIPMENT IN THE WAY OF SMOKE PIPE GASES USE OXYGEN BREATHING APPARATUS AND A TELEPHONE CHEST OR THROAT MICROPHONE SET FOR COMMUNICATION WITH OTHERS IN WORKING PARTY.

OBTAIN NECESSARY EQUIPMENT BEFORE GOING ALOFT.

40.67(26D)
Figure 2-6. —Smoke pipe gases warning sign.

Drawings of the standard warning signs most frequently used have been prepared by the Naval Ship Systems Command.

Figure 2-5 is a High Voltage Warning Sign (NavShips Drawing No. RE 10 B 608B). This sign is to be displayed at all locations where danger to personnel exists, either through direct contact with high voltage or through high voltage arcover. Appropriate guards should also be installed at these locations.

Warning Sign for Personnel Working Aloft in Way of Smoke Pipe Gases (NavShips Drawing No. RE 10 AA 529A) is to be displayed at the bottom and top of access ladders to electronic equipment in the way of smoke pipe gases (fig. 2-6).

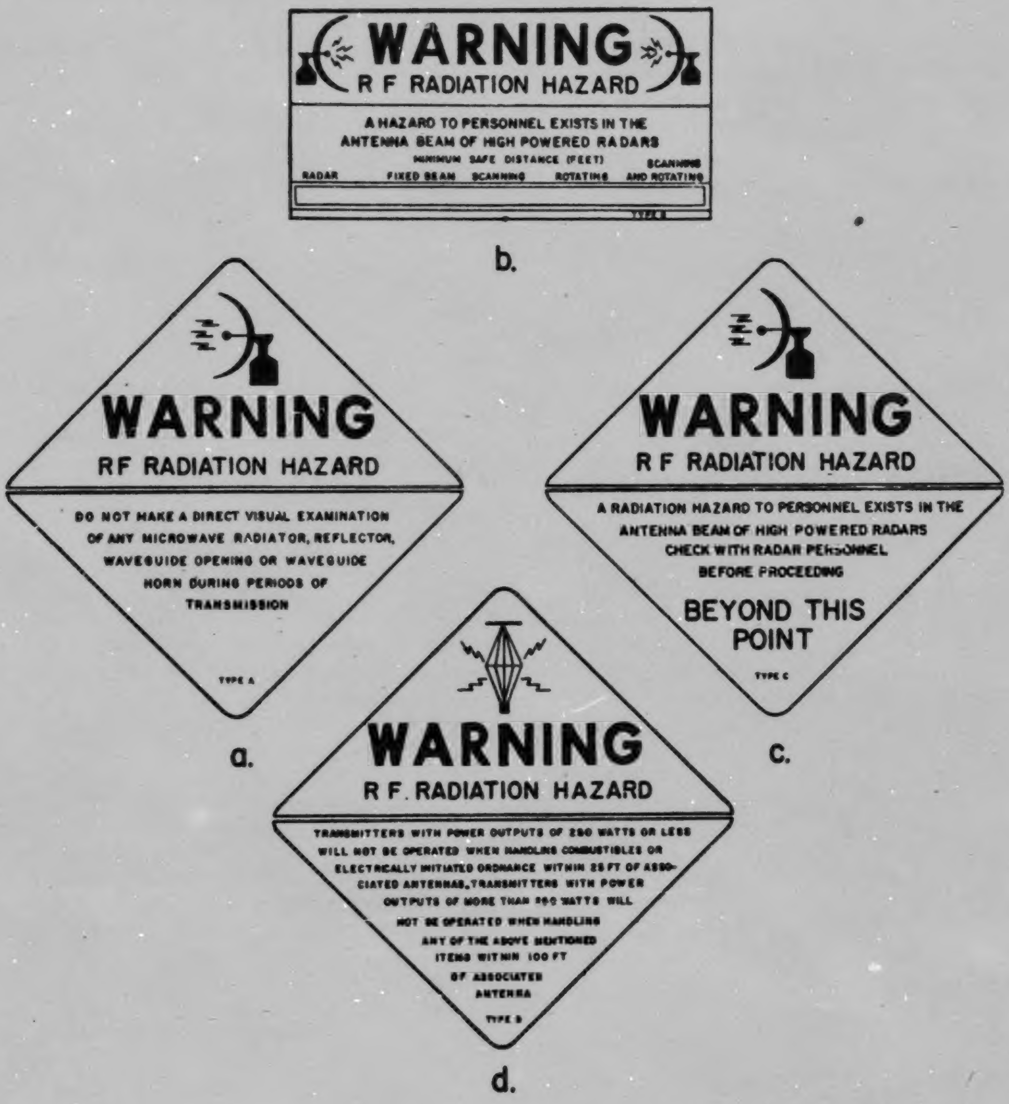
RF Radiation Hazard Warning Sign (NavShips Drawing No. RE 10 D 2282). These signs are of the following four types and are included in the same drawing (fig. 2-7a through d).

1. Type a. To be located on radar antenna pedestals.

2. Type b. To be located on or adjacent to radar set controls.

3. Type c. To be located at eye level at the foot of ladders or other accesses to all towers, masts, and superstructures which are subjected to hazardous levels of radiation.

4. Type d. To be located in radio transmitter rooms in suitable locations in full view of operation personnel.

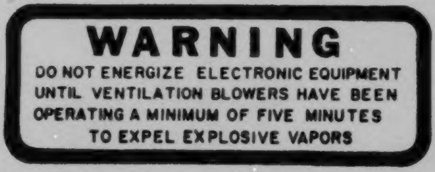

WARNING
R F RADIATION HAZARD
A HAZARD TO PERSONNEL EXISTS IN THE ANTENNA BEAM OF HIGH POWERED RADARS
MINIMUM SAFE DISTANCE (FEET)
RADAR
FIXED BEAM
SCANNING
ROTATING
SCANNING AND ROTATING
TYPE B
b.
WARNING
RF RADIATION HAZARD
DO NOT MAKE A DIRECT VISUAL EXAMINATION OF ANY MICROWAVE RADIATOR, REFLECTOR, WAVEGUIDE OPENING OR WAVEGUIDE HORN DURING PERIODS OF TRANSMISSION
TYPE A
a.
WARNING
R F RADIATION HAZARD
A RADIATION HAZARD TO PERSONNEL EXISTS IN THE ANTENNA BEAM OF HIGH POWERED RADARS CHECK WITH RADAR PERSONNEL BEFORE PROCEEDING
BEYOND THIS POINT
TYPE C
c.
WARNING
R F. RADIATION HAZARD
TRANSMITTERS WITH POWER OUTPUTS OF 250 WATTS OR LESS WILL NOT BE OPERATED WHEN HANDLING COMBUSTIBLES OR ELECTRICALLY INITIATED ORDNANCE WITHIN 25 FT OF ASSOCIATED ANTENNAS. TRANSMITTERS WITH POWER OUTPUTS OF MORE THAN 250 WATTS WILL NOT BE OPERATED WHEN HANDLING ANY OF THE ABOVE MENTIONED ITEMS WITHIN 100 FT OF ASSOCIATED ANTENNA
TYPE D
d.

40.67(76)

Figure 2-7.—RF radiation hazard warning signs.

Warning Plates for Electronic Equipment Installed in Small Craft (NavShips Drawing No. RE 10 A 589). This sign is a warning against the energizing of electronic equipment until ventilation blowers have been operating a minimum of 5 minutes to expel explosive vapors. Although the drawing title indicates this warning plate is to be installed in small craft, it may and should be displayed in all spaces where there is a possibility of the accumulation of explosive vapors (fig. 2-8).

Warning Tags for Marking Open Position of Switches and Cutout Circuits (NavShips 3950 (3-63)-GPO: 1963-0-674658 (on reverse side of tag). This tag is used to indicate a switch which must be left in the OFF or OPEN (safe) position


WARNING
DO NOT ENERGIZE ELECTRONIC EQUIPMENT
UNTIL VENTILATION BLOWERS HAVE BEEN
OPERATING A MINIMUM OF FIVE MINUTES
TO EXPEL EXPLOSIVE VAPORS

40.67(140)
Figure 2-8.—Warning plate for electronic equipment installed in small crafts.

during repairs. These tags are available for ship and shore personnel through normal supply channels (fig. 2-9).

COLD WEATHER SAFETY PRECAUTIONS

Careful instruction and indoctrination of all personnel are necessary to ensure that safety precautions peculiar to cold weather and arctic operations afloat and ashore are observed. Subjects for consideration are listed below:

1. Wear loose clothing—tight clothing and foot gear restrict blood circulation and invite frostbite or trench foot.

Wear dry clothing—outer layers should be water repellent and impervious of rain, snow, and sleet.

2. Avoid overheating—excessive sweating dampens clothing, resulting in poor insulation. Perspiration cools the body even more as it evaporates. It is better to be slightly chilly than excessively sweaty.

3. Wear several layers of thin clothing to allow removal as body heat rises.

4. Work in pairs—check each other for frostbite, since a person can become frostbitten and not realize it. Frostbitten skin becomes whitish or grayish, and the parts feel numb rather than painful.

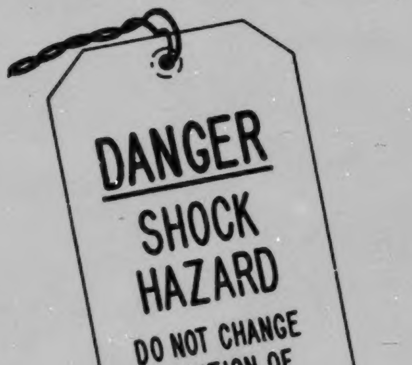
5. Wear sun glasses or goggles with tinted lenses to protect from snow blindness and eye strain.

6. Never touch metal objects with bare hands although seemingly dry; they will freeze to very cold metal.

7. Be very careful when working with fuels and volatile liquids—gasoline will freeze flesh in a matter of seconds.

8. Use wind shields or screens whenever working on exposed equipments.

9. Frequent rest, hot drinks, and food are necessary for efficiency of personnel working on exposed equipment.


DANGER
SHOCK
HAZARD
DO NOT CHANGE
POSITION OF
SWITCH
EXCEPT
BY DIRECTION OF
NAME
RANK
NAVSHIPS 3950(3-63)
☆ GPO:1963-0-674658
(ON REVERSE SIDE OF TAG)

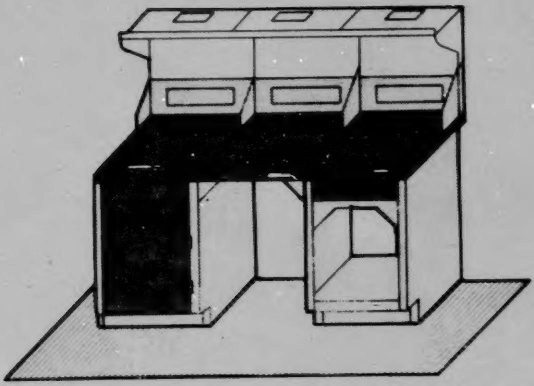
40.67(67B)C
Figure 2-9.–Warning tag for marking open position of switches and cutout circuits.

WORKBENCHES

As an IC Electrician, you will be doing a great deal of equipment testing and repairing on a workbench in the IC room. To avoid getting shocked while working there, you must be careful, and your workbench must be insulated properly.

Figure 2-10 shows the construction features of a safe electric or electronics workbench. Its work surface, or top, is usually 30 inches wide and 4 feet long. The bench must be fastened securely to the deck.

The joints of surrounding portable deck plates must be insulated with epoxy fiberglass strips (MIL-P-18177, type GEE) and secured with nylon screws as delineated in NAVSHIPS Drawing 05-2104467, if the deck plates have vinyl deck covering. Where vinyl deck covering is not used, matting (not less than 3-foot widths) will be



■ Working area (top, top edge, front of doors & drawers) insulated with 3/8-inch Benelex 401 (FSN 9Q-5640-256-5194).

░ All other exposed metal surfaces in the working area (bench front and sides, kneehole sides, underside of top, insulated with 1/8-inch Benelex 401.

▨ Rubber matting may be either grey (FSN 9Q-7220-267-4630) or green (FSN 9Q-7220-913-8751), but a minimum of 3 feet in width.

140.116

Figure 2-10. — Typical electric workbench.

installed over the minimum area necessary to prevent electrical shock. Additionally, a 3-foot width of rubber matting will be installed to insulate the walkway in front of insulated workbenches where vinyl sheet is not specified.

The top and front surfaces of an electric or electronics workbench must be insulated with 3/8-inch Benelex 401. In addition, exposed ends of the workbench and kneeholes under auxiliary work tables must be insulated with 1/8-inch insulation of the same material. Don't defeat the purpose of the insulation by attaching vises, locks, hasps, hinges, or other hardware with metal throughbolts to the metal parts of the workbench. When mounting hardware items, insulate them from the workbench.

The workbench must have grounding leads that are 4 feet long and of type D, size 10 (in accordance with MIL-W-16878). The ground loads must be secured to the ship's structure or at the back of the workbench and equipped at the free end with a 50-ampere power clip (type PC) and insulated sleeving (both conforming to Federal Specification W-C-440). One grounding lead should be installed for every 4 feet of workbench length to ensure positive grounding of the equipment being tested. The grounding leads installed on ships with wooden hulls should be the same as those installed on ships having steel hulls except that the leads should be secured to the ship's electrical grounding system. A bare solid copper conductor, not less than 83,690 circular mils, must be used for the main internal grounding wire.

Test bench receptacle panels should be installed on test benches where power at various voltages and frequencies (other than ships service) are needed for testing equipment. In addition, one symbol 730.1 (or alternate symbol 730.4) receptacle must be installed within 5 feet of each workbench.

The illumination requirements vary between those for general purpose workbenches and workbenches for the repair of instruments, such as typewriters and meters. A warning plate which reads, ELECTRIC SHOCK DANGER DO NOT TROUCH ENERGIZED CIRCUITS must be installed over the workbench. Artificial respiration instructions and a description of an approved method of rescuing personnel in contact with energized circuits must also be posted.

A dummy outlet should be installed near the workbench for checking the grounding conductor on portable tools.

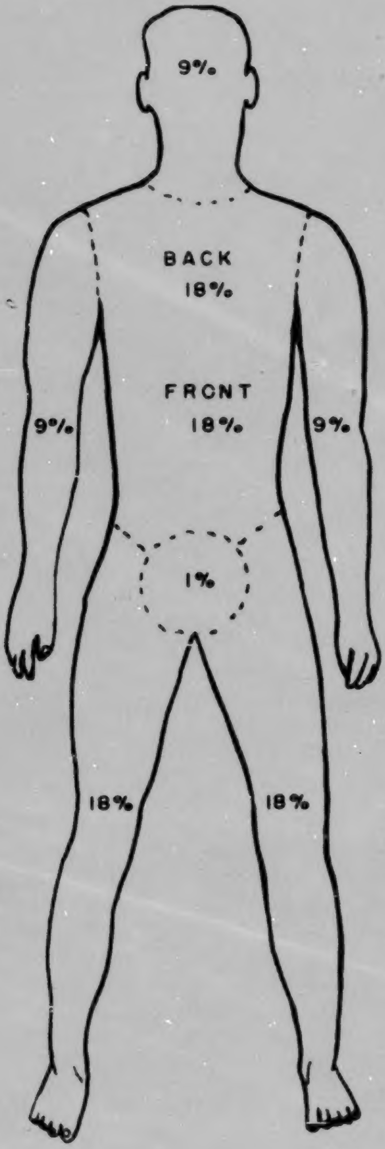
BURNS

The principal dangers from burns are shock and infection. All casualty care measures must be directed toward combating shock, relieving the casualty's pain, and preventing infection.

CLASSIFICATION OF BURNS

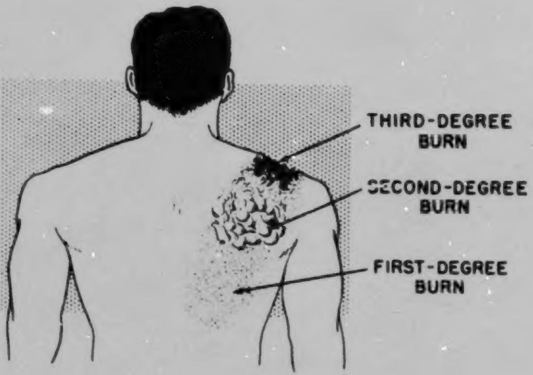
Burns may be classified according to their cause as thermal, chemical, or electrical. Thermal burns are the direct result of heat such as fire, scalding, sun or explosion blast. Chemical burns are produced by chemical action such as battery acid on tissues. Electrical burns may be caused by electrical current passing through tissues or the superficial wound caused by electrical flash.

Bruns may also be classified as first, second, or third degree, based on the depth of skin damage (fig. 2-11). First-degree burns are characterized only by reddening of the skin. Second-degree burns are characterized by blistering of the skin, either early or late. They are the most painful type of burn. The complete thickness



136.31
Figure 2-11. —Rule of Nines for estimating percentage of burned area.

of the skin is not destroyed. Third-degree burns are characterized by complete destruction of the skin with charring and cooking of the deeper tissues. This is the most serious type of burn, for it produces a deeper state of shock and more permanent damage and disfigurement. It



136.32
Figure 2-12. —First, second, and third degree burns.

is not as painful as a second-degree burn because the sensory nerve endings have been destroyed.

Emergency Treatment

The degree of the burn, as well as the skin area involved, determines the procedures used in treatment of burns. Large skin areas requires a different approach than small areas. To estimate the amount of skin area affected, use fig. 2-12.

As a guideline, consider that burns exceeding 20 percent of the body surface endanger life; the old or the very young patient will not tolerate burn injuries well; without adequate treatment, burns of more than 30 percent are usually fatal to adults.

If time and facilities permit caring for patients with superficial burns, the area should be cleaned with soap and water. A simple sterile dressing of fine-mesh, dry gauze is then applied over the area to protect it from infection.

Based on field level casualty treatment conditions, superficial burns include first-degree burns and lesser second-degree burns, which need little attention beyond self-care.

When emergency treatment of the more serious second-degree burns and third-degree burns is required, treat the patient for shock first. Make the patient as comfortable as possible, and protect him from cold, excessive heat, and rough handling.

The loss of body fluids is the main factor in burn shock. Start oral therapy gradually at first by giving him small amounts of hot coffee, tea, fruit juice, or sugar water. Give the drinks frequently but only if the patient is conscious, able to swallow, and has no internal injuries.

To enable trained personnel to determine the kind of treatment required, no medication should be applied to burns during emergency treatment. Pain is closely allied to the degree of shock, and should be relieved as soon as possible. When available, ice water is an effective pain reducer. Flooding with lots of clean, cool fresh water helps also provided that not too much force is used. In electric shock cases, burns may have to be ignored temporarily while the patient is being revived.

After the patient has been treated for pain and shock, a compress and bandage may be applied to protect the burned area. If a universal protective dressing is not available, fine mesh gauze may be substituted. Constricting articles of clothing and ornaments should be removed, and the burned area should be elevated and immobilized.

Patients with extensive deep burns must be evacuated to a medical facility for treatment as rapidly as possible. Pain should be alleviated and shock must be controlled before and during evacuation.

Debris and loose clothing must be removed from burned areas to prevent irritation while the patient is being treated and transported. Clothing that sticks to a burn may be cut around the burn and the adhering cloth allowed to remain until it can be removed at the medical facility. The area of the burn is usually sterile; therefore, care should be taken not to contaminate it.

Chemical Burns

When acids, alkalies, or other chemicals come in contact with the skin or other body membranes, they may cause injuries which are generally referred to as CHEMICAL BURNS. For the most part, these injuries are not caused by heat but by direct chemical destruction of the body tissues. Chemicals which often cause this kind of injury are acids, such as nitric acid, sulphuric acid, hydrochloric acid.

First aid treatment for chemical burns consists of the following measures:

1. WASH OFF THE CHEMICAL WHICH IS CAUSING THE INJURY! This must be done IMMEDIATELY. Flood the affected areas with large amounts of water—preferably water which is clean, fresh, and cool. The best way to get rid of the chemical is to put the casualty under a shower and let the water run as long as necessary.

In order to make the washing process effective, you will of course have to remove all clothing which has come in contact with the chemical. Strip it off as quickly as possible; or, if shears are available, cut it off.

If it is not possible to put the casualty under running water, immerse the affected areas in the largest available amount of water, or pour great quantities of water over him.

It is important to use a large quantity of water, so that the chemical will be diluted and weakened; but you should not apply it forcefully. The skin and tissues which are injured by the action of the chemical will suffer additional damage if the water is applied with too much force.

2. Neutralize any chemical which remains on the skin, by the following applications: for ACID burns, apply a solution of sodium bicarbonate (baking soda) or some other mild alkali. DO NOT ATTEMPT TO NEUTRALIZE ANY CHEMICAL UNLESS YOU ARE SURE THAT YOU KNOW WHAT IT IS AND WHAT SUBSTANCE WILL EFFECTIVELY NEUTRALIZE IT!

3. Wash the affected areas again with fresh water, and dry gently with sterile gauze. Be careful that you do not break the skin or open any blisters. Take all possible precautions to avoid infection.

4. Do whatever you can to relieve the casualty's pain and to treat him for shock. Extensive chemical burns, like extensive heat burns, cause extreme pain and shock.

From this point on, it is usually safe to treat a chemical burn as though it were a true burn, except that petrolatum gauze should not be applied unless you are certain all of the chemical has been removed. Get medical attention for the casualty as soon as possible.

Chemical Burns of the Eye.—Chemical burns of the eye should be treated as follows:

1. Flush the eye IMMEDIATELY with large quantities of fresh, clean water. A drinking fountain may be used to supply a steady stream of water; hold the casualty's head in position so that the water flows from the INSIDE corner of his eye toward the OUTSIDE corner. Do NOT let the water fall directly on the eyeball, and do NOT use any greater force than is necessary to keep the water flowing across the eye.

If you are not near a drinking fountain, have the casualty lie down with his head turned slightly to one side; then pour water into the INSIDE corner of his eye and let it flow across the eyeball to the OUTSIDE corner. Remember that the water must not fall directly upon the eyeball, and that it must not be poured with any greater force than is necessary to sustain the flow across the eyeball.

> NOTE: Because of the intense pain, the casualty may be unable to open his eyes. If this occurs, you must hold the eyelids apart so that the water can flow across the eyeball.

Another way to wash chemical substances from the eye is to have the casualty open and close his eyes several times while his face is immersed in a pan or bucket of fresh water.

2. Cover the eye with a small, thick compress; fasten the compress in place with a bandage or an eyeshield.

3. Get medical care for the casualty as soon as possible.

CAUTION: Do not use anything except water in treating chemical burns of the eye. Do not attempt to neutralize the chemical which has caused the injury. Do not apply any ointment, grease, oil, or salve.

CHAPTER 3

SWITCHES, PROTECTIVE DEVICES, AND CABLES

As an Interior Communications Electrician, you will be working with sophisticated circuitry, consisting of complex equipment, multiconductor cabling, and a variety of switching and protecting devices. The material which follows will give you a basic understanding of the hardware (switches, protective devices, and cable) of interior communications. You will be able to recognize installations, and with limited supervision you will be capable of installing this hardware on board ship after studying the material presented. Not every component used in the Navy is covered, but rather the common installations.

SWITCHES

A basic understanding of switches and their uses is a necessity for the IC Electrician. The Navy uses hundreds of different types of switches.

A switch may be described as a device used for making, breaking, or changing connections in an electrical circuit. Switches are rated in amperes and volts; the rating refers to the maximum allowable voltage and current of the circuit in which the switch is to be used. Since it is placed in series, all the circuit current will pass through the switch; because it opens the circuit, the applied voltage will appear across the switch in the open circuit position. Switch contacts should be opened and closed quickly to minimize arcing; therefore, switches normally utilize a snap action.

Many types and classifications of switches have been developed. A common designation is by the number of poles, throws, and positions. The number of poles indicates the number of terminals at which current can enter the switch. The throw of a switch signifies the number of circuits each blade or contactor can complete through the switch. The number of positions indicates the number of places at which the operating device (toggle, plunger, etc.) will come to rest.

Another means of classifying switches is method of actuation; that is, knife, toggle, push, or rotary. Further classification includes a description of switch action, such as on-off, momentary on-off, and on-momentary off. Momentary contact switches hold a circuit closed or open only as long as the operator deflects the actuating control.

KNIFE SWITCH

The knife switch (fig. 3-1) is the basic power switch from which most modern switches have been developed. A single-pole, single-throw knife switch consists of a single copper blade hinged at one end and designed to fit tightly between two copper jaws, or clips, at the other end. An insulated handle is fastened to the copper blade to open and close the switch. Terminals are provided for connecting the leads.

A two-pole, single-throw knife switch (fig. 3-1A), has two blades with one set of clips for each blade and an insulated handle that operates both blades simultaneously. Double-throw switches (fig. 3-1B) have two sets of clips (one set at each end) so that the blades can be thrown

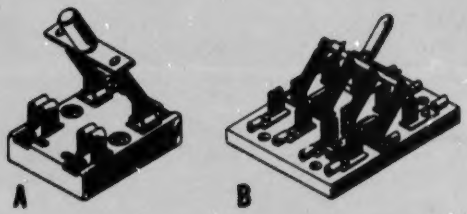


Figure 3-1.—Knife switches.

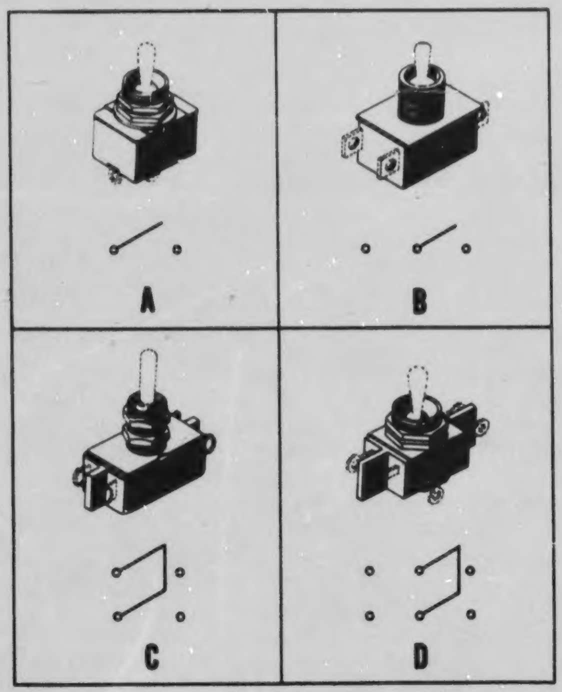


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Figure 3-2. — Toggle switches.

into either set of clips to shift from one circuit to another.

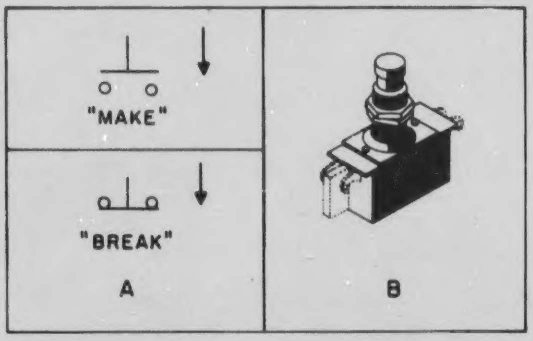
TOGGLE SWITCH

Representative examples of toggle switches are shown in figure 3-2. In part A is shown a single-pole, single-throw (SPST) toggle switch, rates at 20v and 20 amperes, and having 2 solder terminals. The schematic diagram is shown beneath the switch. This switch is used to open or close an electric circuit.

Part B shows a single-pole, double-throw (SPDT) switch, rated at 250v and 1 ampere, and having 3 screw terminals. One of the uses of this switch is to turn a circuit on at one place and to turn if off at another place. It is sometimes called a 3-way switch.

A double-pole, single-throw (DPST) switch is shown in part C. It has 4 solder terminals and is rated at 250v and 1 ampere.

A double-pole, double-throw (DPDT) switch is shown in part D. It has 6 solder terminals and is rated at 125v and 3 amperes.



1.99

Figure 3-3. — Pushbutton switch.

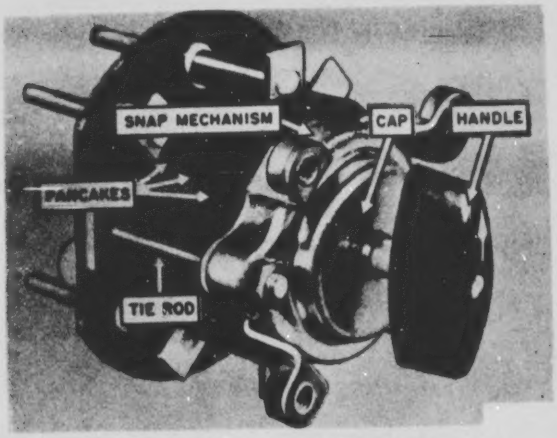
The following types of switches are also used: 3-pole, single-throw (3PST); 3-pole, double-throw (3PDT); 4-pole, single-throw (4PST); and 4-pole, double-throw (4PDT). The voltage ratings range from 20v to 600v, and the amperage ratings range from 1 ampere to 30 amperes.

PUSHBUTTON SWITCH

The normal contact arrangement of a pushbutton switch is either "make" or "break" as shown in figure 3-3. The make-type of switch is usually a start switch; the break-type, a stop switch. Either switch may be locking or nonlocking. There is also a break-make pushbutton switch (not shown).

ROTARY SNAP SWITCH

The rotary snap switch (fig. 3-4) is a device that opens or closes a circuit with a quick motion. A type SR rotary snap switch consists of one or more sections, each of which has a rotor and a stationary member. Movable contacts are mounted on a bushing and stationary contacts are mounted on insulated discs, which are arranged one beneath the other in "pancake" style along the switch shaft. This type of construction has the advantages of shockproofness, compactness, flexibility of circuit arrangements, and protection to the operator. The operator, by rotating the switch handle, triggers a spring and cam arrangement, which, in turn, operates the switch contacts. If the spring should break, further rotation of the handle will eventually cause a projection on the handle's shaft to



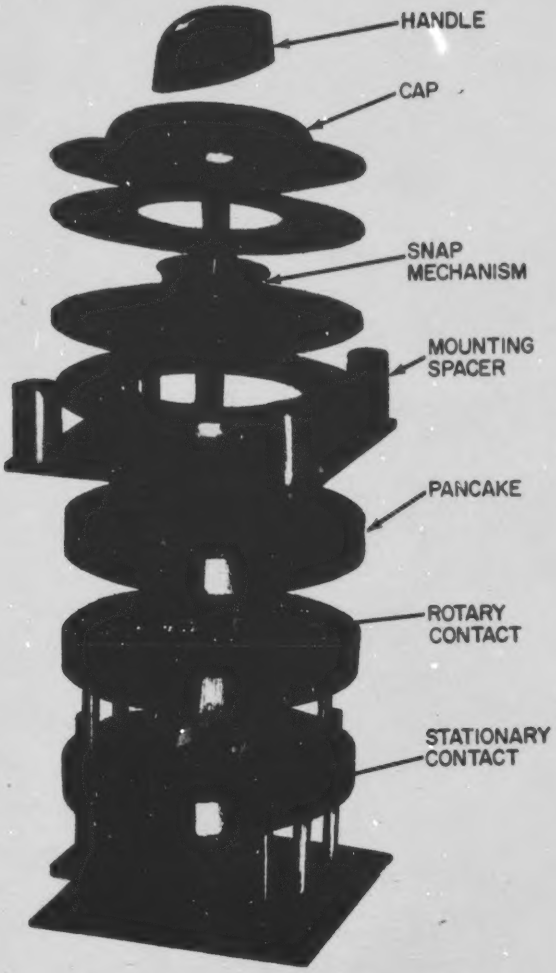
12.69
Figure 3-4.—Type SR rotary snap switch (10 ampere size, 1SR).

contact a projection on the operating shaft to operate the switch. However, the switch-driving shaft and handle will be misaligned from its normal position, and the characteristic snap action will not be apparent.

Snap switches are available in a wide variety of amperage ratings (from 10 to 200), poles, and mountings (bulkhead or panel mounting).

The switch type designation indicates its current rating (1SR is 10 amp, 3SR is 30 amp, and so on); number of poles (3SR3 is 30 amp, 3 pole); switching action (1SR3A is single throw, that is on-off); mounting style (1SR3A1 is front-mounted, back-connected); and enclosure for type switches (3SR4B1-3 is watertight). An exploded view of a type 6SR snap switch is illustrated in figure 3-5.

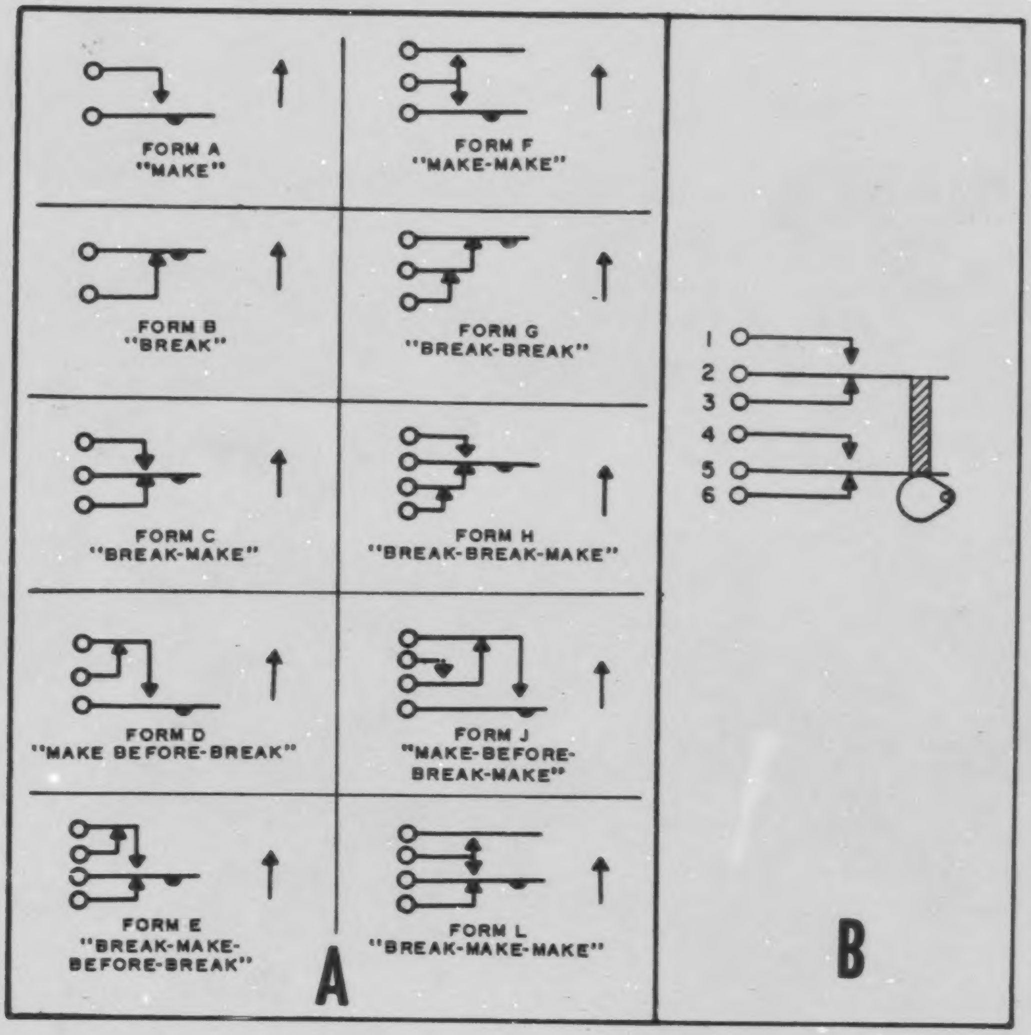
Most snap switches are suitable for 450-volt, 60-hertz, a-c and 250-volt d-c operation. Present 10-ampere switches are suitable for 120-volt operation only, although the switches are sometimes used at higher voltages where the currents are very small. Care must be exercised in the application of multithrow (double-throw and triple-throw) switches. The movable blade, in some cases, is so wide that in moving from one stationary contact to a second, the two stationary contacts will be momentarily bridged by the arc and movable blade, causing a short circuit. Therefore, each time a multithrow switch is to be installed, a careful check should be made on both the switch and the intended circuit to make sure that a switch of the proper current and voltage ratings is used.



140.1
Figure 3-5.—Type SR snap switch—exploded view (60 ampere size 6SR).

PILE SWITCH

Pile switches are constructed so that they open or close one or more electrical circuits. The contacts are arranged in leaf, or pileup, fashion and may be actuated by a rotary, pushing, or sliding motion.


FORM A
"MAKE"
FORM F
"MAKE-MAKE"
FORM B
"BREAK"
FORM G
"BREAK-BREAK"
FORM C
"BREAK-MAKE"
FORM H
"BREAK-BREAK-MAKE"
FORM D
"MAKE BEFORE-BREAK"
FORM J
"MAKE-BEFORE-BREAK-MAKE"
FORM E
"BREAK-MAKE-BEFORE-BREAK"
FORM L
"BREAK-MAKE-MAKE"
A
1
2
3
4
5
6
B

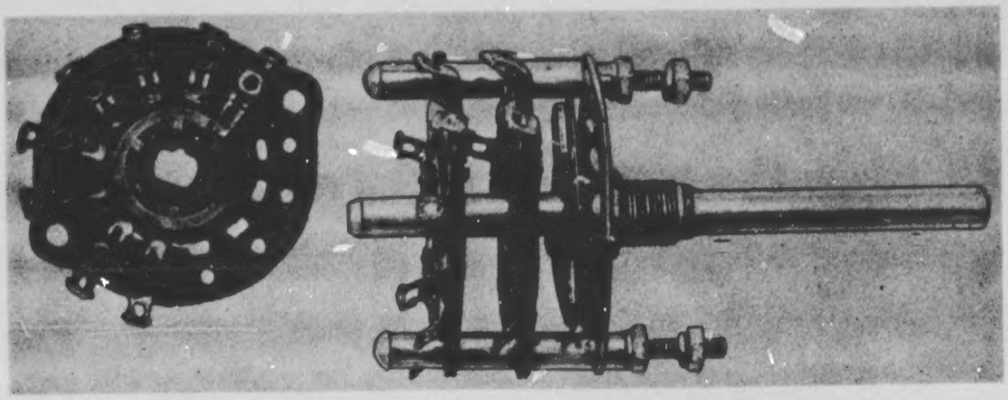
1.99: 104

Figure 3-6. —Pile type switches.

The various basic forms of the contact arrangements in pile switches are shown in figure 3-6A. These basic forms are used by themselves or in combination to make up the contact assembly of a pile switch. Figure 3-6B shows a contact assembly made by combining two "break-make," to form C, contact arrangements. This switch is therefore designated 2C. When the armature is moved upward by the rotary motion of the cam lobe (fig. 3-6B), two circuits are opened and two are closed. This type of switch is commonly used in relays, key switches, and jacks in low-voltage signal circuits.

ROTARY SELECTOR SWITCH

A rotary selector switch may perform the functions of a number of switches. As the knob or handle of a rotary selector switch is rotated, it opens one circuit and closes another. In figure 3-7, the contact is from A to E. If the switch is rotated clockwise, as viewed, the circuit from



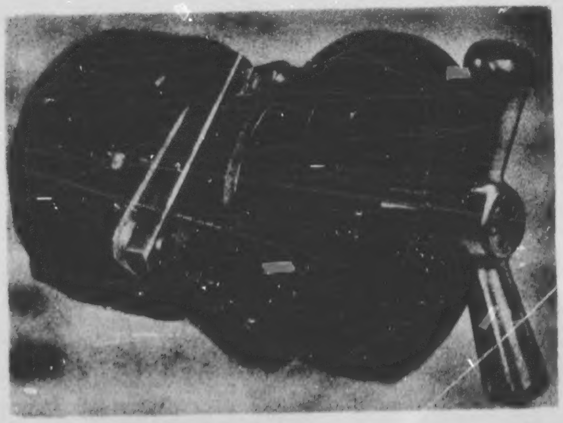
12.68

Figure 3-7.—Rotary selector switch.

A to E is opened and the circuit from A to D is completed. Some rotary switches have several layers of pancakes or wafers. By means of additional wafers, the switch can be made to operate as several switches. Oscilloscope and voltmeter selector switches are typical examples of this type. These switches are more common in civilian equipment than in military hardware.

Type J

The type J multiple rotary selector switch (fig. 3-8) consists of an equal number of rotors and pancake sections. The number of sections required in the switch is determined by the individual application. A shaft with an operating handle extends through the center of the rotors. The movable contacts are mounted on the rotors, and the stationary contacts are mounted on the pancake sections. Each section consists of eight contacts, designated A to H, and a rotor with two insulated movable contacts spaced 180° apart. Each movable contact is arranged to bridge two adjacent stationary contacts. The switch has eight positions. A detent mechanism is provided for proper alignment of the contacts in each position of the operating handle. In one position, the rotor contacts bridge segments A-B and E-F; in the next position, the rotor contacts bridge segments B-C and F-G. Diagonally opposite pairs of contacts are subsequently bridged for the remaining positions.



12.70

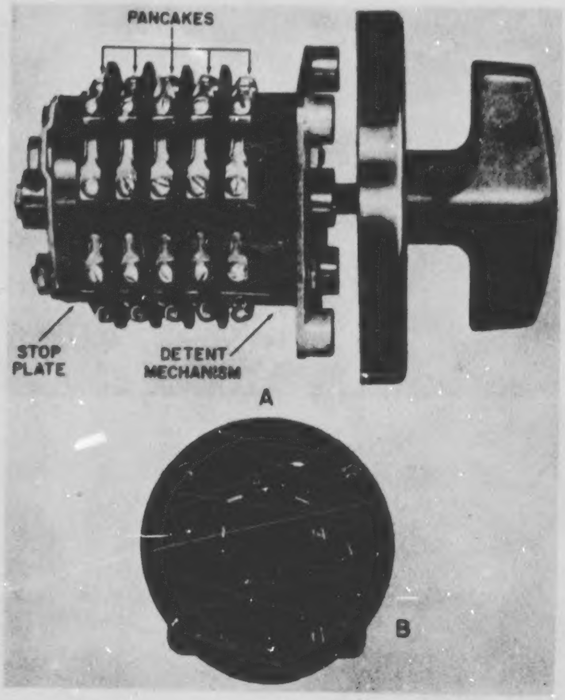
Figure 3-8.—Type J switch.

Type JR

The type JR switch (fig. 3-9) is installed on recent IC switchboards. This switch is smaller in size and more rapidly disassembled than the J switch. These features result in a saving in switchboard space, and facilitate repairs. The JR switch is of the 1JR, 2JR, 3JR, or 4JR type.

The 1JR switch has only one movable contact per section. This movable contact bridges two adjacent stationary contacts.

The 2JR switch has two movable contacts per section, 180° apart. Each movable contact bridges two adjacent stationary contacts.



12.71
Figure 3-9. — Type 4JR switch.

The 3JR switch utilizes one of the stationary contacts as a common terminal. This stationary contact is connected, in turn, to each of the other stationary contacts of the section by a single-wiper contact. The 3JR-type is used for selecting one of several (up to seven) inputs.

The 4JR switch is designed as an "either or both switch" with two movable contacts per section. Each movable contact bridges three adjacent stationary contacts (fig. 3-9B). This switch is used to select either or both of two indicators or synchros. The positions for energizing two indicators are:

90° right — both indicators energized.
45° right — indicator 1 energized only.
0° off.
45° left — indicator 2 energized only.

When the 4JR switch is in the OFF position, both indicators are connected together, but are disconnected from the power supply.

The designations of JR switches are determined by the type of section (rotary and stationary contacts) followed by the number of sections in the switch. For example, a 2JR10 switch denotes a JR switch with ten 2JR sections.

The JR switch is stocked in multiples of 5 sections (up to 25 sections). In some cases, a switch with a number of sections (not a multiple of five) has been installed. If this switch must be replaced, a switch with the next largest number of sections that is a multiple of five should be installed if space permits.

Type JR switches are rated at 120 volts, 60 hertz, and 10 amperes. The switch should not be used on d-c circuits because of the possibility of severely burned contacts when operated slowly (teased). The switch is of the nonshorting type. Although the blade bridges two adjacent contacts simultaneously (for example, contacts 1 and 2 when the switch is operated), the blade breaks contact 1 before making the next alternate contact 3. For example, in the 2JR switch alternate terminals may be connected to an independent source of a-c power without danger of short circuit during movement of the switch blade.

Barriers are also provided between sections to prevent terminals from turning and shorting to adjacent terminals.

If the sections are not uniform the switch will be designated by JRSP followed by the number of sections.

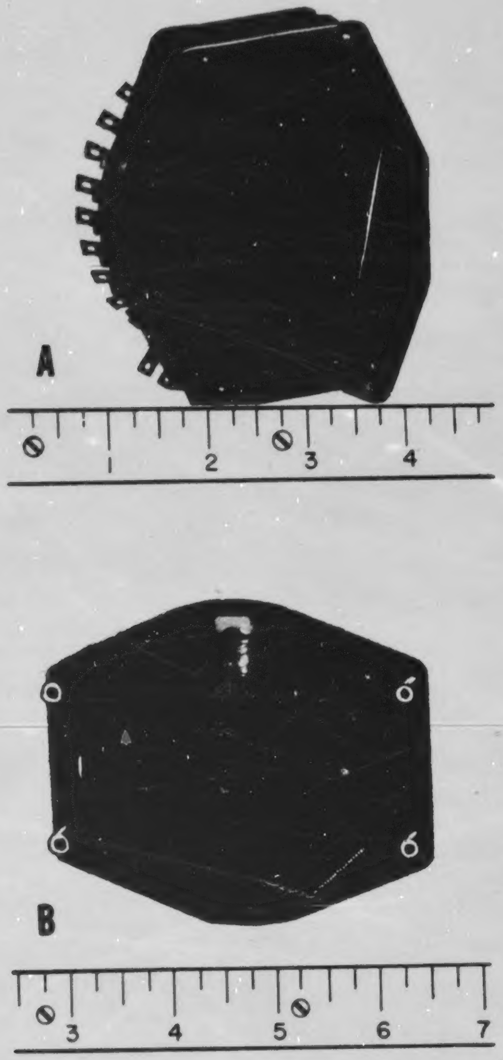
The JR switch has a stop deck, which permits setting the switch to the number of positions desired. Pins or screws inserted in the stop deck immediately after the desired last position, will limit the switch movement to the positions between these points.

Type JL

The JL switch is identical to the JR, except in size, mounting facility, and electrical rating. The diameter of the JL deck is approximately 1 3/4 inches; whereas the diameter of the JR deck is approximately 2 1/4 inches. The rating of the JL switch is 120 volts, 60 hertz, 5 amperes. Standard types are available in 3, 5, and 10 sections. The JL switch has a threaded bushing for single-hole mounting.

Type JA

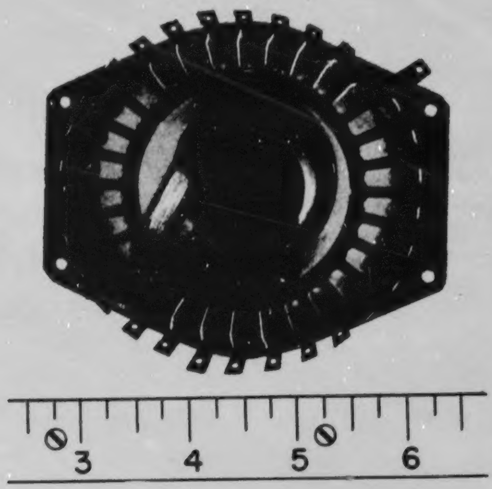
The JA switch (fig. 3-10) was developed primarily for circuit selection in sound-powered telephone applications. It provides a greater number of selections and is a smaller switch



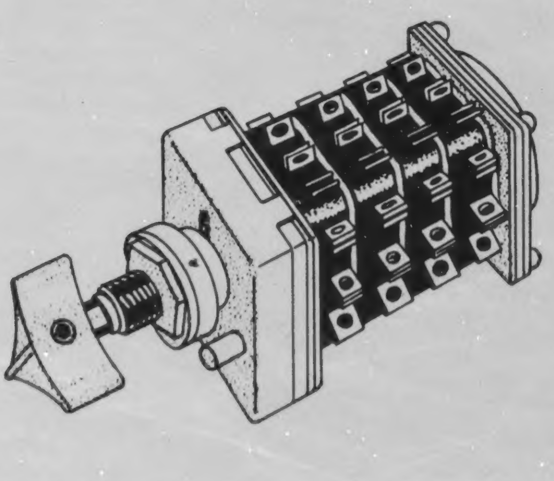
140.2
Figure 3-10.—Type JA switch and detent mechanism.

than the JR switch. The JA switch is furnished only with common rotor sections as shown in figure 3-11. Sixteen-position and 30-position JA switches permit selection of 16 and 30 circuits, respectively. With the JR switch the maximum number of possible selections is 7.

The JA switch also provides lower contact resistance by using either silver or silver-overlay contacts. With brass or copper, an insulating film forms over the contacts which is only broken down if appreciable voltage and power are available in the circuit. However, in sound-powered telephone circuits, there is insufficient power to break down the film, and relatively high resistance results. The silver-to-silver contacts of the JA switch consist of pure silver welded to beryllium copper. Silver



65.75
Figure 3-11.—Type A switch contacts.



140.3
Figure 3-12.—Type JF switch.

or silver-coated contacts are now being utilized for latest type JR switches and other low-current switches. In larger switches, silver (unless alloyed with other metals) is unsatisfactory because it vaporizes too readily due to arcing.

The JA switch is available in 2, 6, and 10 sections. An example of the switch designation is J A6C (16) for a 6-section, 16-position switch; here the first number designates the number of sections, the C indicates common rotor, and the number of parentheses indicates the number of positions.

Type JF

The JF switch (fig. 3-12), was developed primarily to replace toggle switches in the 10 and 20 switch boxes for sound-powered telephone applications.

Because of the problems in making toggle switches watertight, it was necessary to provide a gasketed cover for the 10- and 20-switch boxes, which contained the toggle switches. The cover had to be open when the switches were operated. Therefore, the switch box was not watertight, leading to possible malfunctioning of the switches. In addition, the lack of a strong contact wipe action in toggle switches and the low voltage and current of sound-powered circuits resulted in the formation of an insulating film on the contacts. This film resulted in open circuits or it required several operations of the toggle switch handle before the circuit was initially made.

The JF switch replacement utilizes silver-to-silver conact surfaces and provides a strong wiping action in moving between positions. Open circuit problems have been eliminated in this manner. The blade arrangement provides for a circuit between two adjacent contacts, such as in the 2JR switch previously discussed. The type 2JF has two such blade arrangements per switch deck. The standard switches have 1, 3, and 5 switching decks, which are indicated in the type designation by the number following JF.

The original production of the switches had a detent to limit the switching action to two positions. The present design has a 12-position detent arrangement with adjustable stops. The stops can be adjusted by removing the four screws on the back plate and arranging the stop arms mounted on the switch shaft to give the number of positions desired.

An O-ring on the switch shaft within the mounting bushing prevents water from entering the switch. An O-ring is also provided on the outside of the mounting bushing to give a watertight seal against the panel in which the switch is mounted. These features have eliminated the need for a watertight cover over the switch.

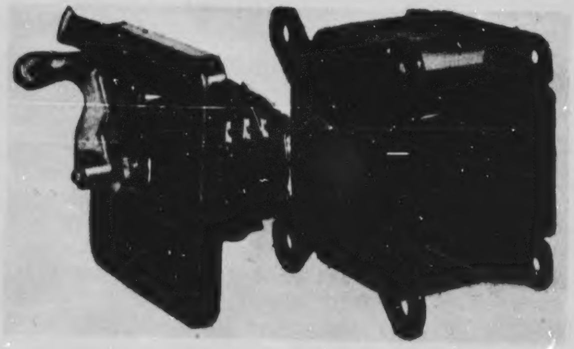
The JF switch is satisfactory for 120 volt, a-c applications up to 1 ampere. It is being used in sound-powered telephones, loudspeakers, microphone stations, and similar low-current equipment.

CAUTION: The switch decks are made of molded nylon material. Be careful in soldering the leads to the switch contacts. Too much heat passing back to the switch deck will destroy the switch deck or damage the insulation between adjacent contacts.

LEVER-OPERATED SWITCH

Many types of lever-operated switches are used in Navy alarm and warning systems to complete an electric circuit to various types of audible and visual alarm signals. The type depends upon the circuit in which it is installed.

Most lever-operated switches utilize JR interiors (fig. 3-13). These switches are operated by a lever with suitable locking plate. In the interests of standardization, two types of interiors are available, each containing three 2JR sections. One type is the JRM-300, which has a spring return mechanism; and the other type is the JR-304, which has a positive detent mechanism. Through slightly different arrangements of pins, lever, and locking plate, various types of switches can be obtained.



140.4

Figure 3-13.—Lever-operated switch (manual contact maker).

Special switches are used where the standard switches cannot. For example, the diving alarm switch on the submarine bridge must be pressure proof. For submarine service, a distinctive shape is used for the operating lever knob or heads of alarm switches in conning tower and control room (where illumination is low) to avoid the possibility of confusion in operating the proper switch. A square-shaped knob is used for the diving alarm switch a star-shaped head for the collision alarm switch, and a standard rounded head for general alarm.

Lever-operated switches are available in 1-, 2-, and 3-ganged types. These switches are used in such systems as the fireroom emergency signal, general alarm, chemical-attack alarm, steering emergency signal, whistle operation, lifebuoy-release, and flight-crash signal.

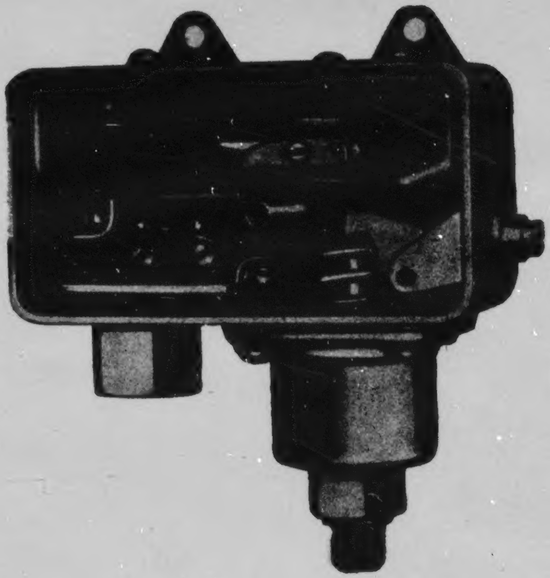
PRESSURE SWITCH

Pressure-operated switches are normally single-pole, single-throw, quick-acting switches. Each contains either a bellows or a diaphragm that works against an adjustable spring. The spring causes the contacts to close automatically when the operating pressure falls below a specified value. The pressure at which the switches operate is adjustable within ranges, such as 0-15, 15-50, and 50-100. Make this adjustment at the screw marked, higher (fig. 3-14). These switches can be used also to indicate an increase in pressure above a predetermined point.

Pressure-operated switches are used with the lubricating oil, low-pressure alarm system; air-pressure alarm system; and booster-feed pressure alarm system.

THERMOSTATIC SWITCH

Thermostatic, or temperature-operated, switches are usually single-pole, single-throw, quick-acting, normally open switches. Each switch contains a bellows that works against an adjustable spring y (fig. 3-15). The spring causes the contacts to close automatically when the operating temperature exceeds a specified value. The bellows motion is produced by a sealed-in liquid that expands with rising temperature. The sensitive element containing this liquid may be built into the switch or located in a remote space and connected to the switch by a capillary tube. The temperature range at which the switches operate is adjustable at x (fig. 3-15).



77.119(140)

Figure 3-14. —Pressure switch type IC/L.

Temperature-operated switches are used with the circulating-water, high-temperature alarm system; cruising-turbine exhaust alarm system, and generator-air, high-temperature alarm system.

MECHANICAL SWITCH

Mechanically operated switches are used in many types of installations, such as wrong direction alarms and valve-position indicators.

Widely used because of their small size and excellent dependability, they are commonly called Microswitches. (Microswitch is a trade name for the switches made by the Microswitch Division of the Minneapolis Honeywell Regulator Company.)

These switches will open or close a circuit with a very small movement of the tripping device. They are usually of the pushbutton variety, and depend on one or more springs for their snap action. For example, the heart of the Microswitch is a beryllium copper spring, heat-treated for long life and unfailing action. The simplicity of the one-piece spring contributes

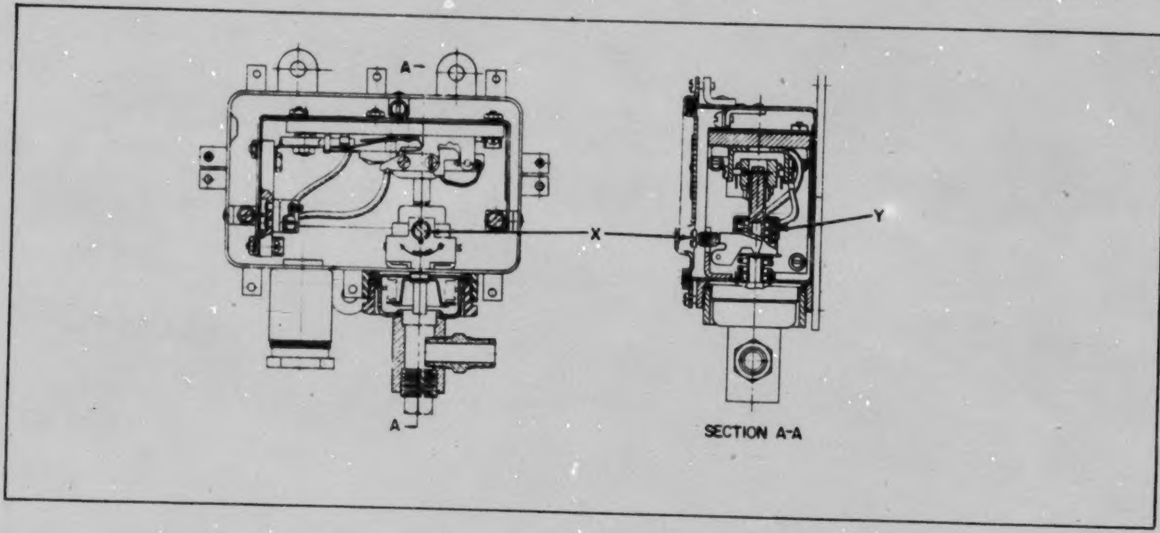


Figure 3-15. — Temperature-operated switch. 140.5

to the long life and dependability of this switch. The basic Microswitch is shown in figure 3-16.

The types of mechanically operated switches are the push-action (type A-S) and the cam-action (types P and P1). The push-operated switch, provided for bulkhead mounting, is a single-throw or multiple-throw, momentary action, normally open push switch. The push-action mechanism utilizes a straight-line movement of the shaft to operate the electrical contacts.

The cam-action switch consists of two single-pole, double-throw Microswitches operated by two adjustable cams mounted on the rotor shaft (fig. 3-17). The cam-action mechanism utilizes a rotary motion of the shaft to move cams,

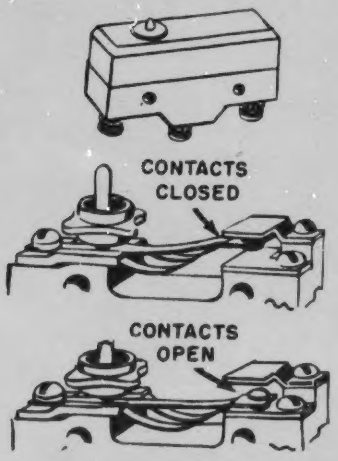


Figure 3-16. — Microswitch. 12.72

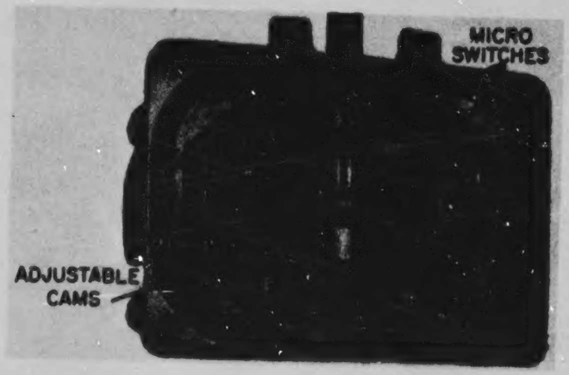


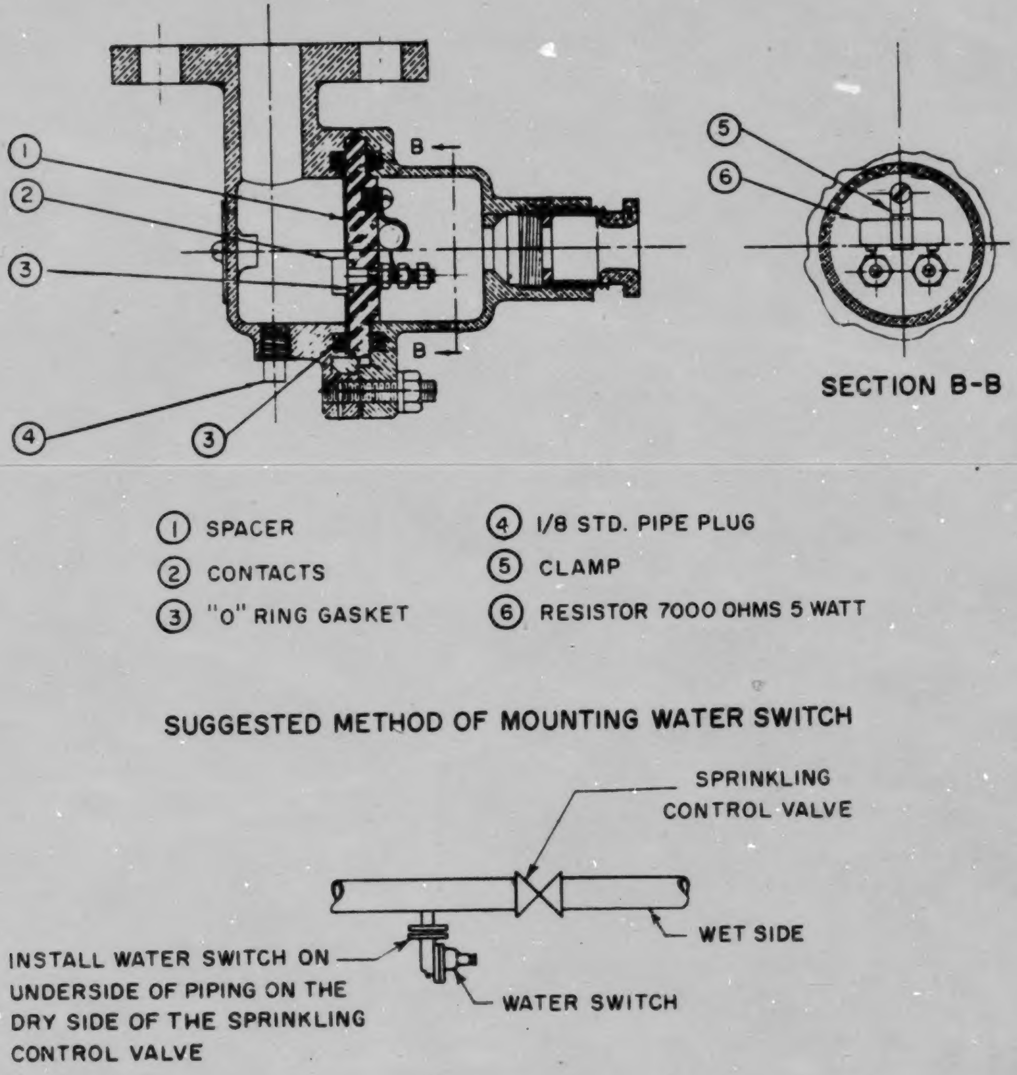
Figure 3-17. — Cam-action mechanical switch. 140.6

which in turn operate sensitive switches. The points of operation of the sensitive switches are varied by adjusting the angular positions of the cams with respect to the shaft on which they are mounted. Mechanical switches are used with the following systems:

QA Air-lock indicator
PW Clutch-position indicator
SP Shaft-position alarm
LS Submersible steering-gear alarm
DW Wrong-direction alarm
TR Hull-opening indicator
VS Valve-position indicator

WATER SWITCH

Water switches consist of a pair of terminals mounted in an insulated base within a cast fitting (fig. 3-18). There is a 7000-ohm, 5-watt


B
B
①
②
③
④
③
⑤
⑥
SECTION B-B
① SPACER
② CONTACTS
③ "O" RING GASKET
④ 1/8 STD. PIPE PLUG
⑤ CLAMP
⑥ RESISTOR 7000 OHMS 5 WATT
SUGGESTED METHOD OF MOUNTING WATER SWITCH
SPRINKLING CONTROL VALVE
WET SIDE
WATER SWITCH
INSTALL WATER SWITCH ON UNDERSIDE OF PIPING ON THE DRY SIDE OF THE SPRINKLING CONTROL VALVE

140.7

Figure 3-18.—Water switch.

resistor connected across the two terminals, which limits the current to the required value for the supervisory circuit when the switch casting is dry. The switch is mounted in the magazine flooding system, and a sprinkling control valve is installed between the switch and the firemain. When the sprinkling control valve is opened, water floods the switch casting and shorts out the 5-watt resistor. With the supervisory resistor shorted, a current of sufficient value to operate the alarm will flow in the circuit.

Water switches are used principally in sprinkling alarm systems (circuit FH).

Liquid Level Float Switch

A relatively new development in indicating alarm and control functions, the liquid level float switch (fig. 3-19) is replacing the float-and-switch combination found in tank and bilge level alarms. This float switch has doughnut-shaped, floatable, magnetic core operating over an encapsulated reed switch. The entire assembly can be mounted at any predetermined level, and the switch can be made normally open or closed by reversal of the core. Level conditions are indicated as normal, above normal, or below normal.

The switch is capable of being connected to the standard alarm unit discussed later.

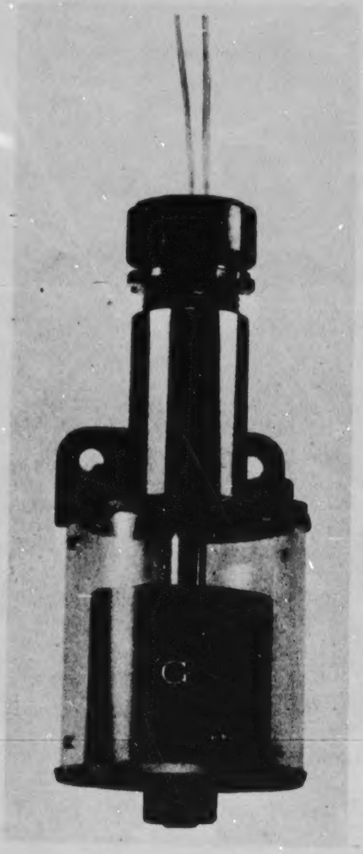
MAINTENANCE OF SWITCHES

Switches should be checked periodically to ensure that all electrical connections and mechanical fastenings are tight. Lockwashers must be in place. Avoid overtightening the packing gland nut on watertight rotary switches as excessive pressure on the switch shaft will cause improper positioning of the switch.

Remove dirt and grease from switch and relay contacts with a cloth moistened with an approved solvent. No lubricants of any kind should be applied to the contacts. Use a burnishing tool for dressing small light contacts.

Clean burned copper contacts with fine sandpaper. Do not use emery cloth. Badly burned contacts should be replaced. Always replace contacts in pairs, rather then replacing a single contact.

Silver contacts require very little maintenance. Removal of the tarnish that forms on silver contacts due to arcing is no longer recommended, as this blackened condition improves the operation of the contacts.



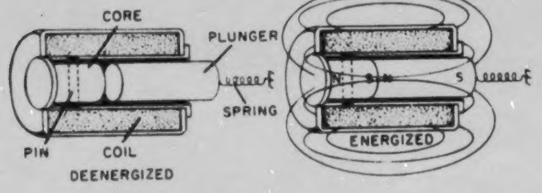
140.63X

Figure 3-19. — Float switch.

When replacing a switch, great care must be taken in tagging leads to ensure proper replacement. Close supervision and proper checkout by an electrical petty officer can ensure against personal injury and equipment damage.

SOLENOIDS

A solenoid is an electromagnet formed by a conductor wound in a series of loops in the shape of a helix (spiral). Inserted within this spiral or coil is a soft-iron core and a movable plunger. The soft-iron core is pinned or held in position and therefore is not movable. The movable plunger (also soft iron) is held away from the core by a spring when the solenoid is deenergized. (See fig. 3-20.)



140.147

Figure 3-20.—Solenoid action.

When current flows through the conductor, a magnetic field is produced. This field acts in every respect like a permanent magnet having both a north and south pole. The total magnetic flux density produced is the result of the generated magnetomotive force and the permeability of the medium through which the field passes.

In much the same way that electromotive force is responsible for current in a circuit, magnetomotive force is responsible for external magnetic effects. The magnetomotive force (mmf) which produces the magnetic flux in a solenoid is the product of the number of turns of wire and the current through the coil. If the current is expressed in amperes, the magnetomotive force is expressed in ampere turns.

From this it can be seen that a prescribed magnetomotive force can be produced by using either a few turns of large wire (high current) or many turns of small wire (low current).

The soft-iron core will also influence the strength of the magnetic flux produced by the coil. The strength of the field is greatly increased by the use of a soft-iron core due to the greater permeability of iron in respect to air. Consequently, by using an iron core a greater flux density can be produced for a given number of ampere turns.

The magnetic flux produced by the coil will result in establishing north and south poles in both the core and the plunger. These poles have such a relationship that the plunger is attracted along the lines of force to a position of equilibrium when the plunger is at the center of the coil. As shown in figure 3-20, the deenergized position of the plunger is partially out of the coil due to the action of the spring. When voltage is applied, the current through the coil produces a magnetic field which draws the plunger within the coil, thereby resulting in mechanical motion. When the coil is deenergized, the plunger returns to its normal position by the spring action. It is interesting to note that the effective strength of the magnetic field on the plunger varies with the distance between the two. For short distances, the strength of the field is strong; and as distances increase, the strength drops off quite rapidly.

Solenoids are used for electrically operating hydraulic valve actuators, carbon pile voltage regulators, power relays, and mechanical clutches. They are also used for many other purposes where only small movements are required. One of the distinct advantages in the use of solenoids is that a mechanical movement can be accomplished at a considerable distance from the control. The only link necessary between the control and the solenoid is the electrical wiring for the coil current.

MAINTENANCE

The first step to be taken in checking an improperly operating solenoid is a good visual inspection. The connections should be checked for poor soldering, loose connections, or broken wires. The plunger should be checked for cleanliness, binding, mechanical failure, and improper alinement adjustment. The mechanism that the solenoid is to actuate should also be checked for proper operation.

The second step would be to check the energizing voltage by use of a voltmeter. If this voltage is too low, the result would be less current flowing through the coil and thereby a weak magnetic field. A weak magnetic field can result in flow, ineffective operation. It could also possibly result in chatter or inoperation. If the energizing voltage is too high, it will in all probability damage the solenoid by either overheating or arcing. In either case the voltage should be reset to the proper value so that further damage or failure will not result.

The solenoid should then be checked for opens, shorts, grounds, and correct resistance with an ohmmeter. If, when you check the resistance of the solenoid the ohmmeter indicates infinity, the solenoid is open circuited and should be replaced. If the ohmmeter reads zero or less than the specified resistance, the coil is shorted and should be replaced. However, if the resistance of the coil is higher than specified (but not infinity) look for a poor contact or a damaged conductor. If the fault cannot be found or corrected, replace the solenoid. Another check possible with the ohmmeter is to determine if the coil is grounded. If the coil is grounded, reinsulate the solenoid.

RELAYS AND CONTACTORS

A RELAY is a magnetically operated switch. The operating coil can be connected in series with a supply line to the load or shunted across the line. A CONTACTOR, like the relay, is a magnetically operated switch, except that the main contacts are designed to carry the heavier current of the load device.

The coil design is influenced by the manner in which the relay is used. When the relay is designed for series connection, the coil is usually wound with a fairly small number of turns of large wire because the load current will be flowing through the winding. When the relay is designed for shunt connection, the coil is wound with a large number of turns of small wire, which will increase the resistance and thus lower the current through the coil.

Because the contacts of relays and contactors may open or close when energized, they can be used as protective devices or control devices or both simultaneously. The basic difference between a-c and d-c relays lies in the armature and magnet core construction.

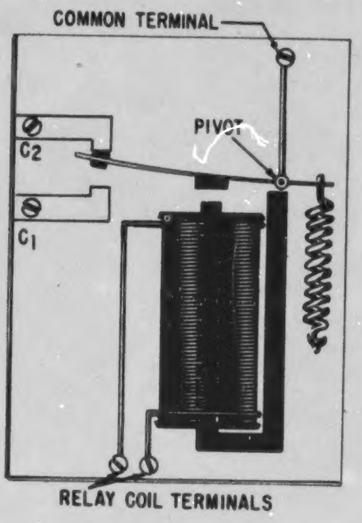
The armature and magnet cores of an a-c relay are made up of laminations, and those of a d-c relay are of solid material. The use of laminations in an a-c relay reduces the heating due to eddy currents. In addition, a copper strap or ring (called shorted turn) is placed near the end of the pole piece of an a-c relay to reduce "chatter" during operation. Because the alternating current is going through a peak, dropping to zero, and going through a peak in the opposite direction and then dropping to zero again during each complete cycle, the coil tends to release the armature each time the current drops to zero and attracts the armature each time it reaches a peak. The SHORTED TURN acts as the secondary of a transformer, the primary of which is the relay operating coil. The current in the shorted turn is out of phase with the current of the operating coil because the copper ring has low-inductive reactance. Thus, when the operating coil flux is zero, the flux produced by the shorted coil is different from zero, and the tendency of the relay to "chatter" is reduced.

RELAYS

Relays are classified according to their use as control relays or power relays. Control relays are usually known simply as relays; power relays are called contactors. Power relays control the heavy power circuits of an electric system. Relays are also classified as open, semisealed, or sealed. The clapper relay (discussed later) is an open relay. Semisealed relays are covered to protect the contacts against the effects of dust, moisture, and foreign matter. A hermetically sealed relay is encased with glass, plastic, or metal. Besides not being affected by changes in temperature and humidity, hermetically sealed relays are tamperproof.

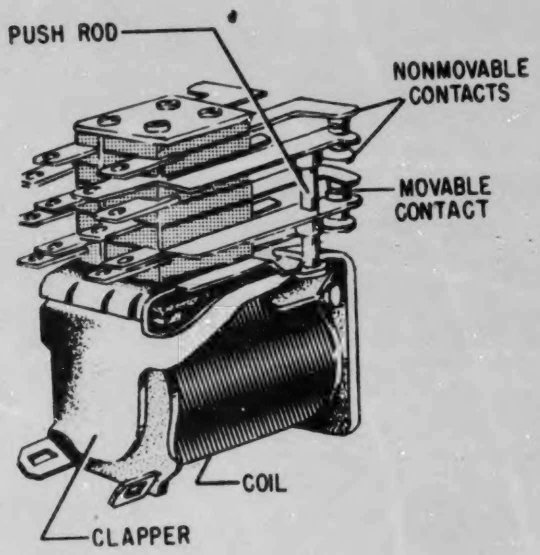
The function of a control relay is to take a relatively small amount of electrical power and use it either to signal or to control a large amount of power. Where multipole relays are used, several circuits may be controlled simultaneously. In automatic relaying circuits, a small electric signal may set off a chain reaction of successively acting relays, which then perform various functions. Control relays can also be used in so-called "lockout" action to prevent certain functions. In some equipment, control relays are used to "sense" undervoltage and overvoltage, reversal of current, excessive currents, phase and amplitude, polarity, etc.

The relay permits the operator to control large amounts of current at other locations in the equipment, the heavy power cables need to be run only to the point of use. Only lightweight control wires are connected to the control switches. Safety is also an important reason for using relays, since high power circuits



140.148

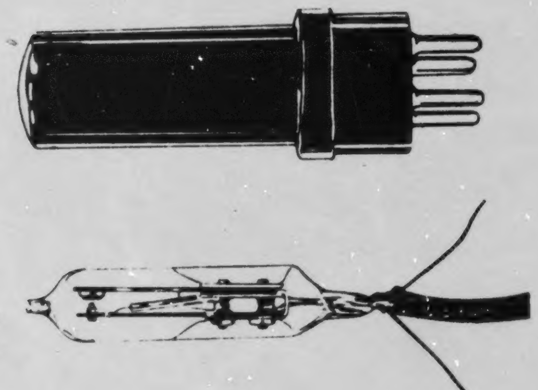
Figure 3-21. —Relay construction.



140.149
Figure 3-22.—Clapper type relay.

can be switched remotely without danger to the operator.

In general, a relay consists of the following components: a magnetic core and associated coil, the contacts, springs, armature, and the mounting. Figure 3-21 illustrates the fundamental construction of a relay. When the circuit is energized, the flow of current through the coil creates a strong magnetic field which pulls the armature to contact C1 which completes the circuit from the common terminal to C1. At the same time it has opened the circuit to contact C2.



140.150
Figure 3-23.—Thermal time delay relay.

The clapper relay (fig. 3-22) contains the same components but has multiple sets of contacts. As the circuit is energized, the clapper is pulled to the magnetic coil. Pulling the arm of the clapper forces the movable contact upward to move the push rod and the upper movable contact. This action could be repeated for as many sets of contacts as required. Thus it is possible to conrol many different circuits simultaneously. To the maintenance man, this type of relay can be a source of trouble. The motion of the clapper arm does not necessarily assure the tandem movement of all the movable contacts. If the push rod was broken, the clapper arm would push the lower movable contact upward but would not move the upper movable contact, thereby not completing the circuit.

Time Delay Relay

A thermal time delay relay (fig. 3-23) is constructed to produce a delayed action when energized. Its operation depends on a thermal action such as that of a bimetallic element being heated. The element is made by welding together two strips of different metals having different thermal expansion rates. A heater is mounted around, or close to, the element with the contacts mounted on the element itself. As the heat causes the element to bend (because of the different thermal expansion rates), the contacts close to operate a relay. The delay time of the bimetallic strips is usually from 1/2 to 1 1/2 minutes and is varied by using metals with different expansion rates or by increasing or decreasing the distance between the fixed and moving contacts.

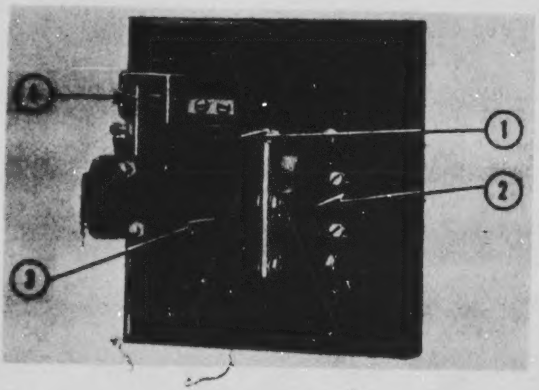
One common form of time delay relay utilizes a lag coil, which is usually a large copper slug located at one end of the winding or a tubular sleeve located between the winding and the core. The lag coil (slug) acts as a short-circuited secondary for the relay coil. The counter magnetomotive force due to the current induced in the coil by the changing coil current, delays the flux buildup or decay in the airgap and hence the closing or opening of the armature. A short slug near the armature end of the core has relatively more effect on the operating time, and one at the heel end has more effect on the release time.

Latch-In Relay

Another type of relay is the latch-in relay. This relay is designed to lock the contacts in the deenergized position until the relay is either manually or electrically reset. Two windings are used, one is the trip coil, and the other the reset coil. When the trip coil is energized, it acts on a spring-loaded armature. The relay's movable contacts are mounted on this armature. After the contacts open they are held in the open position by a mechanical latch. The mechanical latch is unlatched when the reset coil is energized, thus allowing the relay's contact to close again.

SHUNT TYPE CONTACTORS

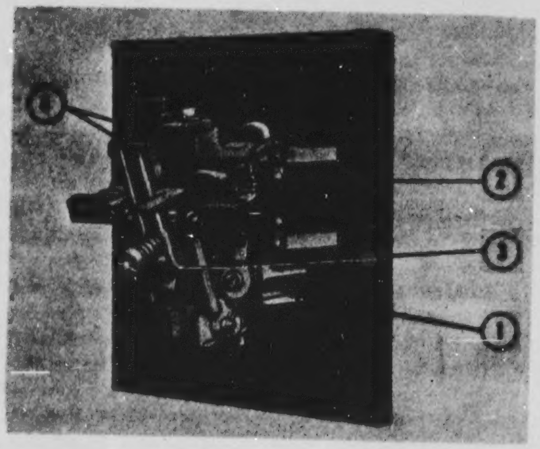
The SHUNT type contactor (connected across to line) operates when line voltage is applied to its operating coil 2 (fig. 3-24). The main contacts, 4 , are arranged to complete or interrupt an electric circuit. In the arrangement the contacts are connected in series with the voltage supply to the controlled circuit. When voltage is applied to the coil, a magnetic pull attracts the armature. 3 , which closes the main contacts. When the voltage supply to the coil is interrupted, the magnetic pull on the armature is removed, and the armature spring pulls it away from the magnet. This action opens the contacts and deenergizes the controlled circuit.



1. Magnetic frame.
2. Operating coil.
3. Armature.
4. Main contacts.

140.9

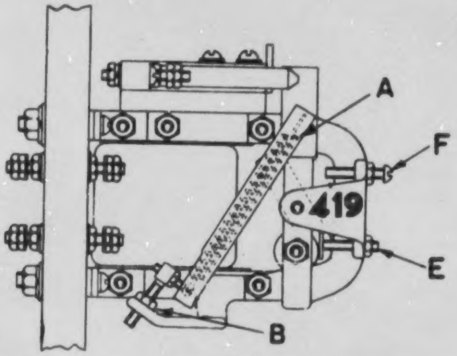
Figure 3-25.—A-c shunt relay.



1. Magnet frame.
2. Operating coil.
3. Armature.
4. Main contacts.

140.8

Figure 3-24.—Shunt type d-c contactor.



140.10

Figure 3-26.—Adjustment of a-c shunt relay.

An a-c SHUNT relay is illustrated in figure 3-25. The basic function of the relay is to make or break an electrical control circuit when the relay coil is energized. To do this, voltage is applied to the operating coil, 2 (connected across the line), which attracts the armature, 3 . When the armature is pulled down, it closes the main contacts, 4 .

The PULL-IN and DROPOUT current values may be adjusted. In figure 3-26 the various adjustment points of the a-c shunt type relay are indicated. The spring, A, and the setscrew, E, control the pickup and dropout values. Before the relay is adjusted, screw F should be set to clear the armature when the armature is in the closed position. The pull-in value can be raised by increasing the spring tension or by increasing the armature gap.

SERIES TYPE CONTACTORS

The SERIES type relays are operated by circuit current flowing through the coil or coils. This feature makes it possible to use the relay as a field failure relay, or for any application where the relay operation is in response to changes in circuit current flow.

There are two adjustments on the two-coil relay. One adjustment sets the difference between the opening and closing current values. The other adjustment sets the range of operating values. Usually, the operating adjustment is the only one required.

MAINTENANCE OF RELAYS

The relay is one of the most dependable electromechanical devices in use, but like any other mechanical or electrical device it occasionally wears out or becomes inoperative.

When current flows in one direction through a relay, the contacts may be subjected to an effect called "cone and crater." The crater is formed by the transfer of the metal of one contact to the other contact, the deposit being in the form of a cone.

Under normal operating conditions, most relay contacts spark slightly; this will cause some minor burning and pitting of the contacts. Contact clearances or gap settings must be maintained in accordance with the relay's operational specifications. Relay contact surfaces must be kept clean and in good operating condition. Some relays are equipped with ball-shaped contacts which, in many applications, are superior to the flat contacts. Dust or other substances do not collect as readily on a curved surface. In addition, a ball-shaped contact can penetrate film more easily than a flat contact. Avoid flattening or otherwise altering a contact's rounded surfaces. Relays similar to the shunt relay, figure 3-25 have replaceable contacts that should be maintained similar to switch contacts. See maintenance of switches at the beginning of this chapter.

Many relays have been damaged or ruined because the contact points were cleaned with sandpaper or emery cloth instead of a burnishing tool. The use of sandpaper and emergy cause bending of the contact springs and other damage. Attempts to straighten the contact springs with longnose pliers cause further damage, eventually requiring replacement of the relays. Burned and pitted contacts cannot be repaired by burnishing; the relay should be replaced. Figure 3-27 illustrates a burnishing tool being used on a relay.

Burnishing tools are stocked in supply activities and may be obtained through normal supply channels. When using this tool, be sure to clean it thoroughly with alcohol; do not touch the tool surface with the fingers prior to use.

Another useful tool in relay maintenance is a point bender (fig. 3-28) for straightening bent relay contact springs. It can be fabricated locally from 0.125-inch diameter rod stock shaped as indicated in the figure, or it may be obtained through normal supply channels.

Potential relay trouble can be spotted by checking for charred or burned insulation on the relay and for darkened or charred terminal

140.151

Figure 3-27. — Burnishing tool.

140.152

Figure 3-28. — Point bender.

leads coming from the relay. Both of these indicate overheating. If there is any indication that a relay has overheated the cause of overheating should be determined. An experienced senior petty officer should determine whether the relay requires replacement. An occasional cause of relay trouble, not due to the relay itself, is overheating caused by loose power terminal connectors.

It is recommended that covers not be removed from semisealed relays in the field. Removal of a cover in the field, although it might give useful information to a trained eye, may result in entry of dust or other foreign material which may cause poor contact or an open circuit. Removal of the cover may also result in loss of or damage to the cover gasket.

Should an inspection determine that a relay has exceeded its safe life, the relay should be removed immediately and replaced wih another of the same type. The replacement relay must have the same characteristics or ratings, such as voltage, amperage, type of service, number of contacts, continuous or intermittent duty.

PROTECTIVE DEVICES

Most protective devices are designed to interrupt the power to a circuit or unit under abnormal conditions, such as short circuits, overloads, high or low voltage, and excessive current. The most common types of protective devices are fuses, circuit breakers, and overload relays.

FUSES

A fuse is a protective device used to open an electric circuit when the current flow exceeds a safe value. Fuses are made in many styles and sizes for different voltages and currents, but they all operate on the same general principle. Each fuse contains a soft metal link that melts and opens the circuit when overheated by excessive currents.

Plug Fuse

A plug fuse has a piece of zinc-alloy wire mounted in a porcelain cup with a metal cover. A threaded contact base similar to a lamp socket is provided so that the fuse can be screwed into a socket in the fuse block. Plug fuses are used on small-capacity circuits ranging from 3 through 30 amperes at not more than 250 volts. Some plug fuses have small mica windows so that the fusible link can be observed. The plug fuse is not normally used in naval vessels and is seldom used in commercial applications; however, they can be found in older buildings and houses.

Cartridge Fuse

A cartridge fuse consists of a zinc-alloy link enclosed in a fiber, plastic, ceramic, or glass cylinder. Some fiber and plastic fuse cylinders are filled with nonconducting powder. The smaller fuses are used in circuits up to 60 amperes and are made in the FERRULE, or round-end cap type. Large sizes with short flat blades attached to the end caps are rated from 65 through 200 amperes. These blades fit tightly into clips on the fuse block similar to knife-switch clips.

Cartridge fuses are made in capacities of 1 through 1000 amperes for voltages of 125, 250, 500, 600, and 1000 volts. Fuses intended for 600- and 1000-volt service are longer and do not fit the same fuse holders as fuses intended for lower volt service. Fuses of different ampere capacity are also designed for different sizes of holders. For example, fuses of 1 through 30 amperes fit one size of holder, and fuses with capacities of 35 through 60 amperes fit a different size holder.

Cartridge fuses in IC equipment are of various sizes, such as the miniature FO2 or FO3 (1 1/4- by 1/4-inch) fuse rated from 0.1 through 30 amperes at 125 volts and the midget FO9 (1 1/2- by 13/32-inch) fuse rated for 0.1 through 30 amperes at 125 volts. The standard 2- by 9/16-inch fuse is rated from 1 through 30 amperes, 500 volts for a-c service and 250 volts for d-c service. Fuses above 60-ampere capacity have knife-blade contacts and increase in diameter and length as the capacity increases.

Before fuses of greater than 10 ampere capacity are pulled, the switch for the circuit should be opened. Whenever possible, this precaution should be taken before any size fuse is pulled or replaced. Approved fuse pullers must be used for removing fuses. Fuses should never be short circuited or replaced with fuses of larger current capacity.

Time Delay Fuse

Time delay fuses are used in motor supply circuit, for example, where overloads and motor-starting surges of short duration exist. Common trade names for these fuses are Fusetron and Slo-Blo. A conventional fuse of much higher rating would be required to prevent blowing of the fuse during surges. Because of its high rating, this fuse could not provide necessary protection for the normal steady state current of the circuit.

The time delay fuse is rated as to its time lag characteristic with a minimum blowing time at some overload current. A typical rating is "12 seconds minimum blowing time at 200 percent rated current."

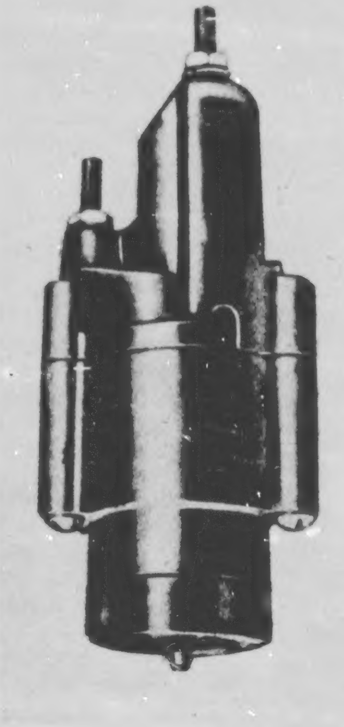
Selection of Proper Fuses

Individual fuses are provided on the IC switchboards for each associated circuit. A separate fuse in each line of each circuit has the effect of considerably increasing the maximum short circuit current that the fuses can safely interrupt. It also provides greater protection to the remaining circuits energized from the same bus in case of a possible defect in one fuse.

In general, fuse ratings should be approximately 10 percent above the maximum continuous connected load. In circuits, such as call bell systems and alarm systems where only a small portion of the circuit is likely to be operated at any one time, the fuse rating should be 10 percent greater than the load of one associated group of signals operated, or 15 percent of the total connected load, whichever is greater. Where the circuit incorporates branch fuses, such as those associated with the fire-control switchboards, the rating of the fuses on the IC switchboard should be 20 percent above the maximum connected load to provide sufficient margin so that branch fuses will always blow before the main fuses. In no case should the fuse rating be greater than two and one-half times the rated capacity of the smallest cable in the circuit. If too large a fuse were used, a fire hazard would exist.

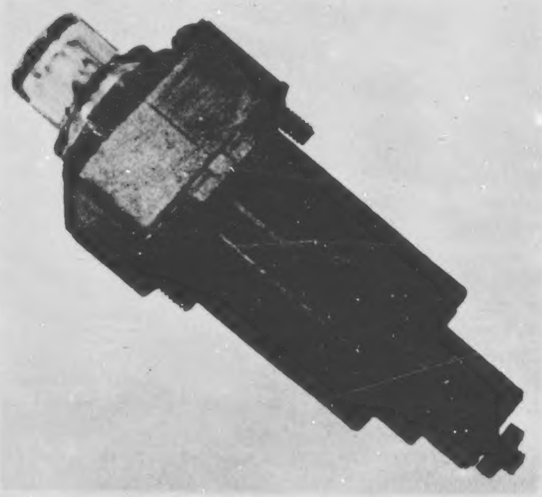
Fuse Holders

The type EL-1 fuse holder consists of a base and a plug, as shown in figure 3-29. The base extends behind the panel, and into it is screwed the plug containing the fuse. Behind a hole in the plug cap is small neon lamp which serves as a



140.12

Figure 3-29.—Fuse holder, type EL-1.



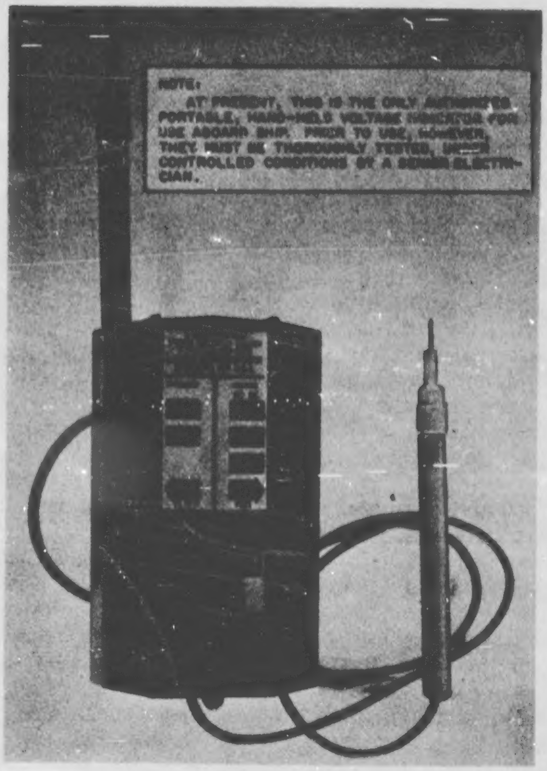
140.13
Figure 3-30. — Fuse holder, type FHL12U.

blown-fuse indicator, lighting when the energized circuit through the holder is interrupted by the blowing of a fuse. Series resistors of different values are used with the lamp on 125- and 250-volt circuits, except for the MIDGET holder, which is rated for 125 volts only.

The types FHL10U, FHL11U, and FHL12U (fig. 3-30) consist of fuse holder body and a fuse carrier. The body is mounted on the panel, and the carrier with the fuse placed in the clips is inserted into the body in a manner similar to inserting a bayonet type lamp into a socket. Removal of the fuse is accomplished by pushing and turning the fuse carrier in a counterclockwise direction, again similar to the removal of a bayonet base lamp. The types FHL10G and FHL11G accommodate 1 1/4- by 1/4-inch fuses. The type FHL10G will hold two fuses and can therefore be used to fuse both sides of the line, or, in conjunction with a type FHL11G, will fuse a three-phase line. Type FHL12G will accommodate 1 1/2- by 13/32-inch fuses. When these fuse holders are mounted in a dripproof enclosure they maintain the dripproof integrity. They also possess the ruggedness and the vibration and high-impact shock resistance necessary for shipboard use.

The extensive use of low-voltage power supplies has required the use of incandescent lamps in place of neon glow lamps in some indicator light circuits. A modification of the FHL10U fuse holder provides a third terminal connected to a 28-volt incandescent lamp in the cap. By insertion of a suitable resistor between the load terminal and the added terminal, the lamp will be energized by a sufficient voltage to become visible when the fuse has blown. In some low-voltage fuse holders the resistor and lamp are included within the clear plastic cap. Low-voltage fuse holders should not be used in sensitive, low-current equipment. Where an overload condition occurs and the fuse blows, the low resistance indicator circuit may pass sufficient current to damage the equipment.

Due to the design of certain fuses and in cases where space does not permit indicator



NOTE:
AT PRESENT, THIS IS THE ONLY AUTHORIZED PORTABLE, HAND-HELD VOLTAGE INDICATOR FOR USE ABOARD SHIP. PRIOR TO USE, HOWEVER, THEY MUST BE THOROUGHLY TESTED, UNDER CONTROLLED CONDITIONS BY A SENIOR ELECTRICIAN.

73.32(140B)
Figure 3-31. — Voltage tester.

type fuse holders, separate indicator light circuits are mounted on a panel and connected in parallel with separately mounted fuses and fuse clips. In some cases an alarm circuit in the form of a bell or buzzer takes the place of the indicator light.

Voltage Tester

The most commonly used voltage tester now available to the fleet is the multifrequency type shown in figure 3-31. This tester has electronic circuitry and glow lamps to indicate voltage, frequency, and polarity. One, two, or three lamps are used to indicate the a-c or d-c voltage. The other lamps identify the a-c frequency (60 or 400 hertz) or whether the d-c circuit being tested has negative polarity applied to either the red probe or the black probe. This tester is designed for operation on 28 to 550 volts a-c or 28 to 600 volts d-c.

Before being taken from the shop and used on a circuit, a voltage tester must be tested for proper operation on a known voltage source, such as the electric shop test panel.

If your voltage tester is inoperative, turn it in to your leading petty officer for repair or replacement.

Never use a lamp in a "pigtail" lamp holder as a voltage tester. Lamps designed for use on low voltage (120 v) may explode when connected across a higher voltage (440 v). In addition, a lamp would only indicate the presence of voltage, not the amount of voltage. Learn to use and rely on standard test equipment.

TROUBLESHOOTING FUSED CIRCUITS

An electrical system may consists of a comparatively small number of circuits or, in the larger systems, the installation may be equal to that of a fair sized city.

Regardless of the size of the installation, an electrical system consists of a source of power (generators or batteries) and a means of delivering this power from the source to the various loads (lights, motors, and other electrical equipments).

From the main power supply the total electrical load is divided into several feeder circuits and each feeder circuit is further divided into several branch circuits. Each final branch circuit is fused to safely carry only its own load while each feeder is safely fused to carry the total current of its several branches. This reduces the possibility of one circuit failure interrupting the power for the entire system. The feeder distribution boxes and the branch distribution boxes contain fuses to protect the various circuits.

The distribution wiring diagram showing the connections that might be used in a lighting system is illustrated in figure 3-32. An installation might have several feeder distribution boxes, each supplying six or more branch circuits through branch distribution boxes.

Fuses F_1, F_2, and F_3 (fig. 3-32) protect the main feeder supply from heavy surges such as short circuits or overloads on the feeder cable. Fuses A-A1 and B-B1 protect branch No. 1. If trouble develops and work is to be done on branch No. 1, switch S_1 may be opened to isolate this branch. Branches 2 and 3 are protected and isolated in the same manner by their respective fuses and switches.

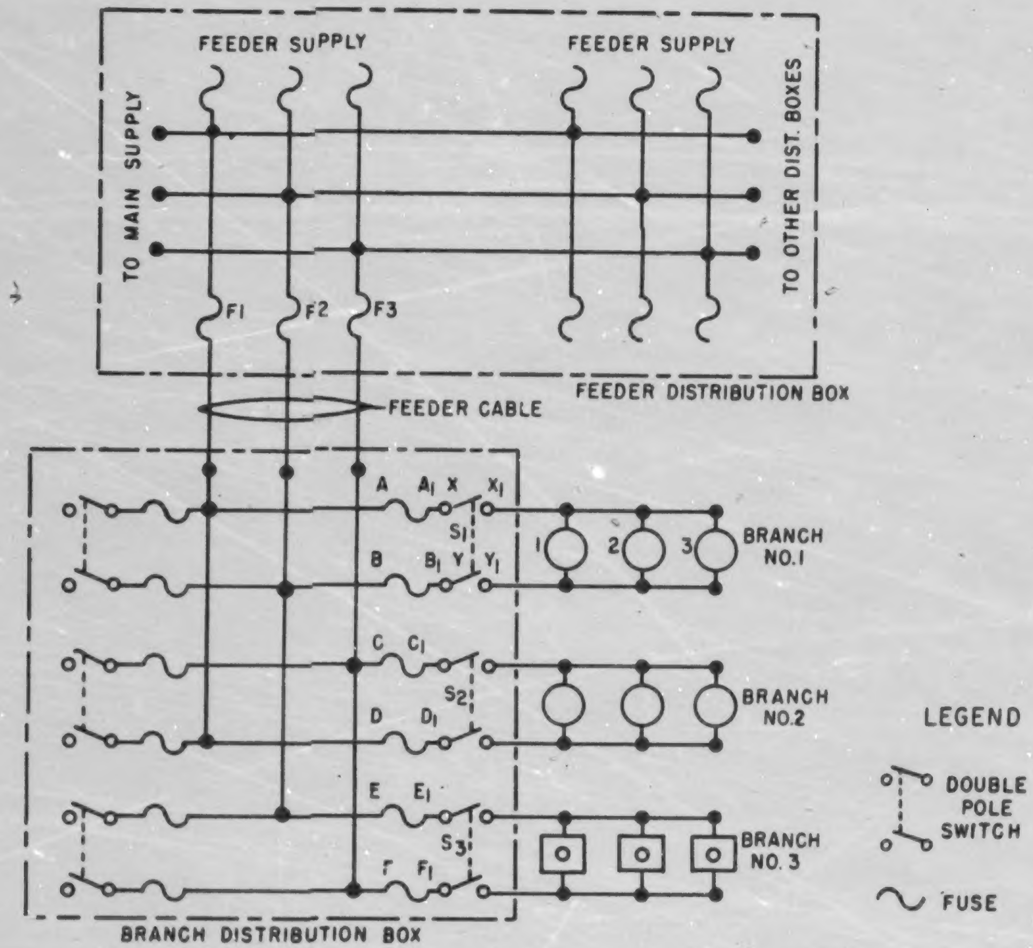
Branch Circuit Tests

Usually, receptacles for portable equipment and fans are on branch circuits separate from lighting branch circuits. Test procedures are the same for any branch circuit. Therefore, a description will be given on the steps necessary to (1) locate the defective circuit and (2) follow through on that circuit and find the trouble.

Assume that, for some reason, several of the lights are not working in a certain section. Because several lights are out, it will be reasonable to assume that the voltage supply has been interrupted on one of the branch circuits.

To verify this assumption, first locate the distribution box feeding the circuit that is inoperative. Then make sure that the inoperative circuit is not being supplied with voltage. Unless the circuits are identified in the distribution box, the voltage at the various circuit terminations will have to be measured. For the following procedures, use the circuits shown in figure 3-32 as an example circuit.

To pin down the trouble, connect the voltage tester to the load side of each pair of fuses in the branch distribution box. No voltage between these terminals indicates a blown fuse or a failure in the supply to the distribution box. To find the defective fuse, make certain S_1 is closed, then connect the voltage tester across A-A1, and next across B-B1 (fig. 3-32). The full-phase voltage will appear across an open fuse, provided circuit continuity exists across the branch circuit. However, if there is an open


FEEDER SUPPLY
FEEDER SUPPLY
TO MAIN SUPPLY
TO OTHER DIST. BOXES
F1
F2
F3
FEEDER DISTRIBUTION BOX
FEEDER CABLE
A
A1
X
X1
S1
B
B1
Y
Y1
1
2
3
BRANCH NO.1
C
C1
S2
D
D1
BRANCH NO.2
E
E1
S3
F
F1
BRANCH NO. 3
BRANCH DISTRIBUTION BOX
LEGEND
DOUBLE POLE SWITCH
FUSE

65.57

Figure 3-32. — Three-phase distribution wiring diagram.

circuit at some other point in the branch circuit, this test is not conclusive. If the load side of a pair of fuses does not have the full-phase voltage across its terminals, place the tester leads on the supply side of the fuses. The full-phase voltage should be present. If the full-phase voltage is not present on the supply side of the fuses, the trouble is in the supply circuit from the feeder distribution box.

Assume that you are testing at terminals A-B (fig. 3-32) and that normal voltage is present. Move the test lead from A to A1. Normal voltage between A1 and B indicates that fuse A-A1 is in good condition. To test fuse B-B1, place the tester leads on A and B, and then move the lead from B to B1. No voltage between these terminals indicates that fuse B-B1 is open. Full-phase voltage between A and B1 indicates that the fuse is good.

This method of locating blown fuses is preferred to the method in which the voltage tester leads are connected across the suspected fuse terminals, because the latter may give a false indication if there is an open circuit at any point between either fuse and the load in the branch circuit.

CIRCUIT BREAKERS

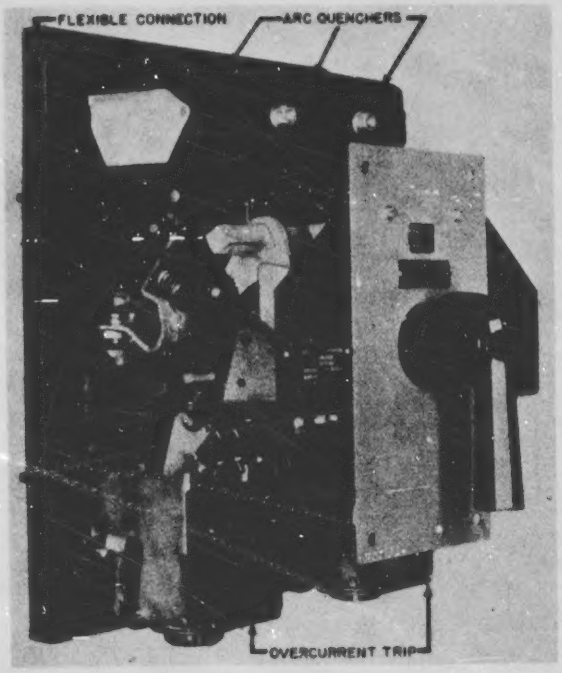
Circuit breakers have three fundamental purposes: (1) to provide circuit protection and to perform normal switching operations; (2) to isolate a defective circuit while repairs are being made, and (3) to help start large motors in manual and automatic bus transfer.

Air circuit breakers are used in switchboards, switch gear groups, and in distribution panels. The types installed on naval ships are ACB, AQB, AQB-A, AQB-LF, NQB-A, ALB and NLB. They are called air circuit breakers because the main current carrying contacts interrupt in air.

Circuit breakers are available in manually or electrically operated types which may or may not provide protective functions. Some types may be operated both ways, while others are restricted to one mode.

ACB

Figure 3-33 shows the exterior of a type ACB circuit breaker. This circuit breaker is designed for either manual local closing or electrical remote closing. It has an open metallic frame construction mounted on a drawout mechanism and is normally used to supply heavy loads and protect the equipment from high short circuit currents.



27.73
Figure 3-33.—Type ACB circuit breaker.

Type ACB circuit breakers are used to connect ship's service and emergency generators to the power distribution system. They are also used on bus ties and shore connection circuits, and on some feeder circuits from the ship's service switchboard. In these applications, they operate usually in conjunction with a pilot device, such as a relay or switch. An electrically operated circuit breaker has an electromagnet which acts as a solenoid to trip a release mechanism that causes the breaker contacts to open. The energy to open the breaker is derived from a coiled spring. The electromagnet is controlled by the contacts in the pilot device.

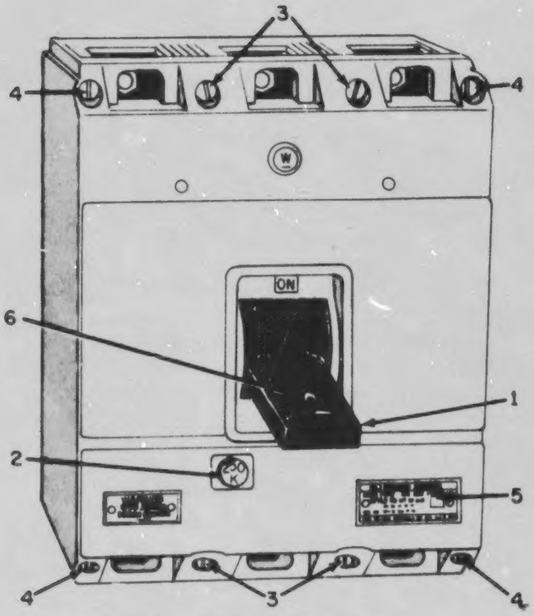
Circuit breakers designed for high currents have a double-contact arrangement. The complete contact assembly consists of the main bridging contacts and the arcing contacts. All current carrying contacts are high-conductivity, arc-resisting silver or silver alloy inserts.

Each contact assembly has a means of holding the arcing to a minimum and extinguishing the arc as soon as possible. The arc control section is called an arc chute or arc runner. The contacts are so arranged that when the circuit is closed, the arcing contacts close first. Proper pressure is maintained by springs to ensure the arc contacts close first. The main contacts then close.

When the circuit opens, the main contacts open first. The current is then flowing through the arc contacts, which prevents burning of the main contacts. When the arc contacts open, they pass under the front of the arc runner, creating a magnetic field that blows the arc up into the arc quencher and quickly opens the circuit.

Type ACB circuit breakers are either hand operated or electrically operated. The high interrupting types of ACB breakers are electrically operated from a remote location, making it unnecessary for personnel to approach them in order to open or close the circuit.

No circuit breaker, regardless of type, should be worked on without opening the circuit. Remember that certain terminals may have voltage applied to them even though the breaker is open. Aboard ship, power may be supplied to either end of the circuit breaker.



1. OPERATING HANDLE SHOWN IN LATCHED POSITION
2. AMPERE RATING MARKER
3. MOUNTING SCREWS
4. COVER SCREWS
5. BREAKER NAMEPLATE
6. COTTER KEY HOLE

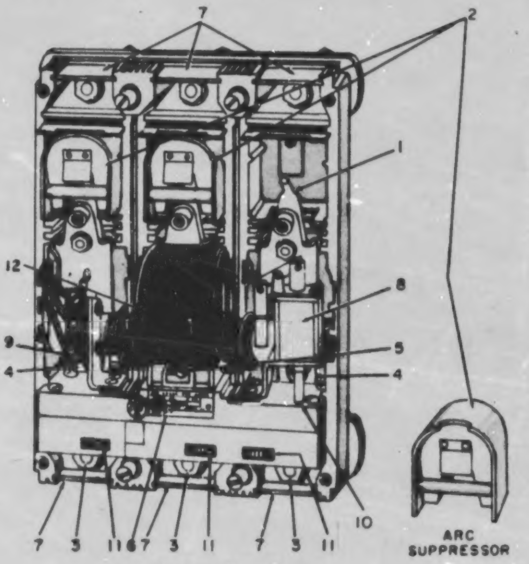
77.241
Figure 3-34.—AQB-A250 circuit breaker complete, front view.

AQB

Type AQB circuit breakers (fig. 3-34) are mounted in supporting and enclosing housings of insulating material and have direct-acting automatic tripping devices. They are used to protect single-load circuits and all feeder circuits coming from a load center distribution panel. Where the requirements are low enough, the type AQB may be used on generator switchboards. When it becomes necessary to replace one of the older type circuit breakers, it should be replaced by the newer AQB-A101, AQB-A250, AQB-A400, AQB-A600, or AQB-A800 as required.

AQB-A250.—The newer AQB type circuit breakers such as the AQB-A250 have several advantages over the older types. The outside dimensions of these new breakers are the same for both the two-pole and three-pole circuit breakers. They are designed for front or rear connections as required and may be mounted so as to be removable from the front without removing the circuit breaker cover. The voltage ratings of the AQB-A250 are 500 volts a-c, 60 hertz or 250 volts d-c.

The 250 part of the circuit breaker type designation indicates the frame size of the circuit breaker. The current carrying parts of a 250-ampere frame size circuit breaker have a continuous rating of 250 amperes. Trip units (fig. 3-35) for this breaker are available with current ratings of 125, 150, 175, and 250 amperes.



(1) STATIONARY CONTACT
(2) ARC SUPPRESSORS
(3) TERMINAL STUD NUTS AND WASHERS
(4) TRIP UNIT LINE TERMINAL SCREW-OUTER POLES
(5) TRIP UNIT LINE TERMINAL SCREW-CENTER POLE
(6) TRIP UNIT NAMEPLATE
(7) TERMINAL BARRIERS
(8) SHUNT TRIP OR UNDERVOLTAGE DEVICE
(9) AUXILIARY SWITCH
(10) HOLE FOR SHUNT TRIP OR UNDERVOLTAGE RELEASE PLUNGER
(11) INSTANTANEOUS TRIP ADJUSTING WHEELS
(12) COTTER KEY HOLE

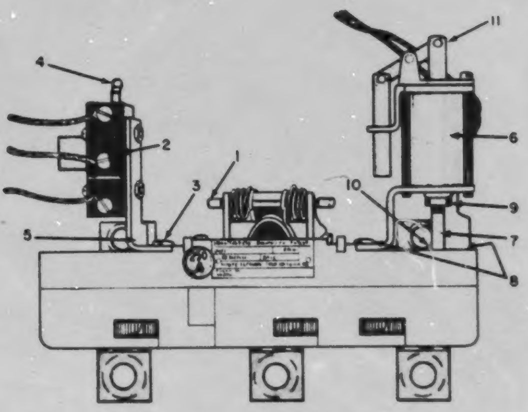
77.242
Figure 3-35.—AQB-A250 circuit breaker front view, cover and arc suppressor removed.

The trip unit houses the electrical tripping mechanisms, the thermal element for tripping the circuit breaker on overload conditions, and the instantaneous trip for tripping on short circuit conditions.

In addition 100, 160, and 250 ampere rating trip units with a special calibration are available for use with generator circuit breakers. Regardless of the trip unit used the breaker is still a 250 ampere frame size. The automatic trip devices of the AQB-A250 circuit breaker and "trip free" of the operating handles; in other words the circuit breaker cannot be held closed by the operating handle if an overload exists. When the circuit breaker has tripped due to overload or short circuit, the handle rests in a center position. To reclose after automatic tripping, move the handle to the extreme OFF position which resets the latch in the trip unit, then move the handle to the ON position.

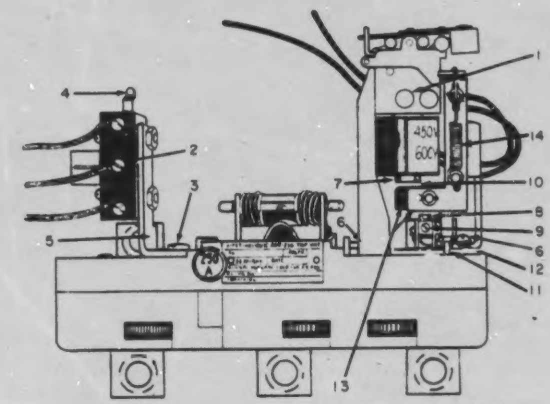
The AQB-A250 circuit breaker may have auxiliary switches, shunt trip (for remote tripping), or undervoltage release attachments when so specified. However, a shunt trip cannot be provided in the same breaker with an under-voltage release since in all cases the shunt trip coil is momentary rated and must be connected in series with a circuit breaker auxiliary switch. Figure 3-36 shows a trip unit with shunt trip and a trip unit with undervoltage trip. The coil for a shunt trip has a dual rating for a-c and d-c voltages whereas the undervoltage trip coils are wound for a specified voltage such as 450 a-c or 250 d-c and have rated pickup and dropout values. The instantaneous trip setting of the AQB-A250 trip units may be adjusted by the instantaneous trip adjusting wheels shown in figure 3-35. Though not shown in the figure these trip adjusting wheels are marked for five positions, LO-2-3-4-HI, the trip unit label (not shown) will list the instantaneous trip value obtainable for each marked position. Identical settings must be made on each pole of the circuit breaker. NEVER remove a circuit breaker cover to perform adjustments while the circuit breaker is in the closed (ON) position.

Terminal mounting block assemblies used in conjunction with the circuit breaker (fig. 3-37) for drawout mounting, consist of terminal studs in terminal mounting blocks of insulating material. The terminals of the circuit breaker have slip type connectors which engage the terminal studs as shown in figure 3-37. Two mounting blocks are usually required for each circuit breaker. This method of connecting a circuit breaker to a bus or circuit is known as



(1) TRIP UNIT LATCH PIN
(2) AUXILIARY SWITCH
(3) AUXILIARY SWITCH MOUNTING SCREWS
(4) AUXILIARY SWITCH LEVER
(5) AUXILIARY SWITCH MOUNTING BRACKET
(6) SHUNT TRIP
(7) SHUNT TRIP TUBULAR CORE
(8) SHUNT TRIP MOUNTING SCREWS
(9) TUBULAR CORE LOCK NUT
(10) HOLE FOR SHUNT TRIP PUSH PIN
(11) SHUNT TRIP PLUNGER

A

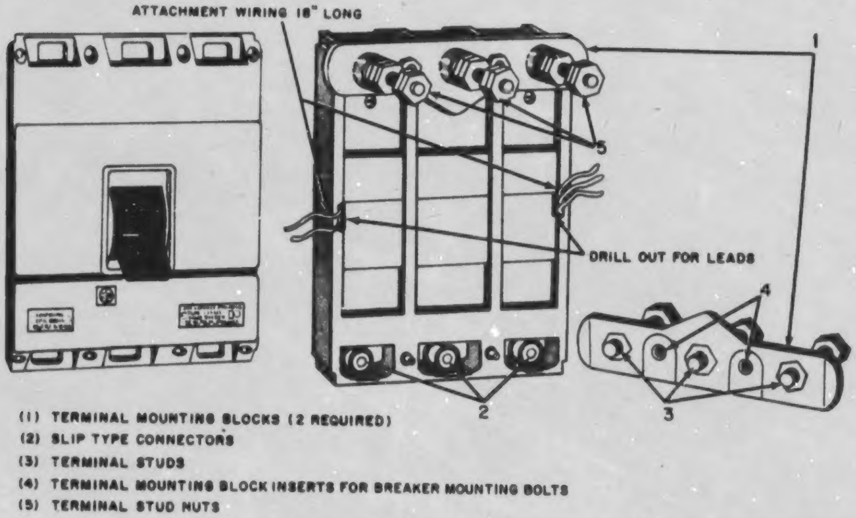


(1) UNDERVOLTAGE RELEASE
(2) AUXILIARY SWITCH
(3) AUXILIARY SWITCH MOUNTING SCREWS
(4) AUXILIARY SWITCH LEVER
(5) AUXILIARY SWITCH MOUNTING BRACKET
(6) UNDERVOLTAGE RELEASE MOUNTING SCREWS
(7) UNDERVOLTAGE RELEASE MAGNET
(8) ARMATURE TRAVEL ADJUSTING SCREW
(9) SET SCREW FOR ARMATURE TRAVEL ADJUSTING SCREW
(10) ARMATURE - MAGNET AIR GAP
(11) UNDERVOLTAGE RELEASE PUSH ROD
(12) LOCK NUT FOR PUSH ROD
(13) UNDERVOLTAGE RELEASE ARMATURE
(14) ARMATURE RETAINING SPRINGS

B

77.243:.244

Figure 3-36.—AQB-A250 trip unit: (a) with shunt trip and auxiliary unit; (b) with undervoltage release and auxiliary switch.


ATTACHMENT WIRING 18" LONG
1
5
DRILL OUT FOR LEADS
4
2
3
(1) TERMINAL MOUNTING BLOCKS (2 REQUIRED)
(2) SLIP TYPE CONNECTORS
(3) TERMINAL STUDS
(4) TERMINAL MOUNTING BLOCK INSERTS FOR BREAKER MOUNTING BOLTS
(5) TERMINAL STUD NUTS

77.245

Figure 3-37.—AQB-A250 circuit breaker rear view, with terminal mounting blocks.

a "back connected circuit breaker." Circuit breakers which have solderless connectors attached to their terminal are commonly called "front connected circuit breakers." The interrupting rating of the AQB-A250 circuit breaker is 20,000 amperes at 500-volts a-c to 15,000 amperes at 250-volts d-c.

AQB-LF 250.—The AQB-LF 250 circuit breaker (fig. 3-38), combines the standard AQB circuit breaker and a current limiting fuse unit which interrupts the circuit when the current is in excess of the interrupting rating of the breaker. Constructed as one compact unit, the AQB-LF circuit breaker incorporates the current limiting fuses (fig. 3-39) as integral parts of the circuit breaker. The common trip features of the AQB-A250 circuit breaker are retained and trip units from 125 to 250 amperes are available for use in the AQB-LF 250.

The current limiting fuse unit is designed so that it trips the breaker and opens all poles if any current limiting fuse (fig. 3-40) is blown. After a fuse has blown, the circuit breaker cannot be reclosed until the blown fuse is replaced. Any attempt to remove the fuse unit when the circuit breaker is in the closed position will automatically trip the breaker.

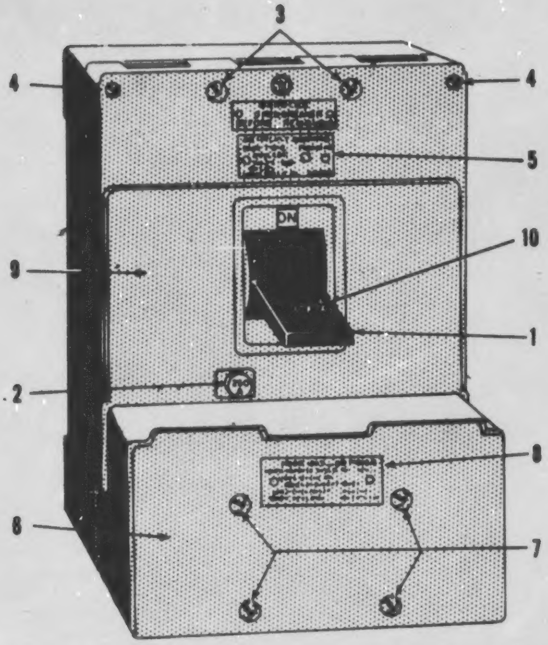
The AQB-LF250 circuit breaker is interchangeable with the AQB-A250 circuit breaker except a larger cutout is required in the switchboard front panel to accommodate the fuse unit of the AQB-LF250.

The AQB-LF250 circuit breaker is a 250 ampere frame size, however, the circuit breaker has an interrupting rating of 100,000 amperes at 500-volts a-c whereas the AQB-A250 circuit breakers interrupting rating is 20,000 amperes at 500-volts a-c.

While the AQB-A250 circuit breaker could be either front or back connected, the AQB-LF250 is designed only for back (drawout type) connection, using the same type of slip connectors terminal studs as shown in figure 3-37.

NQB

The NQB-A250 circuit breaker (fig. 3-41) is similar to the AQB-A250 circuit breaker except the NQB-A250 has no automatic tripping devices. This type of circuit breaker is used for circuit isolation and manual transfer applications. This NQB-A250 is still a 250-ampere frame size as



(1) OPERATING HANDLE SHOWN IN LATCHED POSITION
(2) AMPERE RATING MARKER
(3) BREAKER MOUNTING SCREWS
(4) COVER SCREWS
(5) BREAKER NAMEPLATE
(6) FUSE UNIT ASSEMBLY
(7) FUSE UNIT MOUNTING SCREWS
(8) FUSE UNIT NAMEPLATE
(9) BREAKER COVER
(10) COTTER KEY HOLE

77.246

Figure 3-38.—AQB-LF250 complete circuit breaker, front view.

the current carrying parts of the breaker are capable of carrying 250 amperes. Technically this circuit breaker is simply a large on and off switch. Some types of AQB and NQB breakers are provided with electrical operators mounted on the front of the breaker. These are geared motor devices for remote operation of the breaker handle.

ALB

Type ALB circuit breakers are designated low-voltage, automatic circuit breakers. The continuous duty rating ranges from 5 through 200 amperes at 120 volts a-c or d-c. The breaker is provided with a molded enclosure, drawout type connectors, and nonremoveable and nonadjustable thermal trip elements.

This circuit breaker is a quick-make, quick-break type. If the operating handle is in the tripped (midway between ON and OFF) position, indicating a short circuit or overload, the operating handle must be moved to the extreme off position, which automatically resets the overload unit and the breaker can again be closed.

NLB

Circuit breakers type NLB are identical to ALB types except that they have no automatic tripping device and are used only as on-off switches.

Maintenance

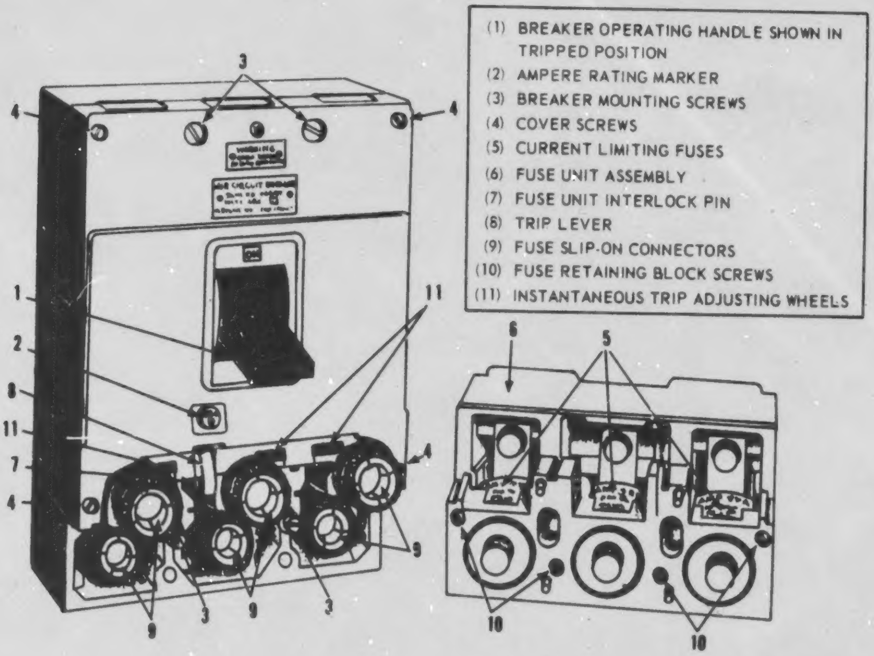
Metal locking devices are available that can be attached to the handles of AQB type circuit breakers to prevent accidental operation. All breaker handles are now provided with a 3/32-inch hole permitting fastening the locking device with a standard cotter pin. NavShips Technical Manual, Chapter 9600, lists the stock numbers for three different sizes of breaker handle locking devices.

Circuit breakers require careful inspection and cleaning at least once a year (more frequently if subjected to unusually severe service conditions). The special inspections follow.

No work should be undertaken on circuit breakers without first obtaining approval of the electrical or engineer officer.

Before working on a circuit breaker be aware of its time delay characteristics, whether short time, long time, or instantaneous trip are provided. The adjustments for tripping of the circuit breakers are made and sealed at the factory; no unauthorized changes should be made to their trip settings because these changes may completely disrupt their intended functions of protection. Improper tripping action is corrected best by replacement of the entire breaker assembly, especially where trouble is encountered in the contact assemblies.

A special inspection should be carefully made of each pair of contacts after a circuit breaker has opened on a heavy short circuit. Before working on a circuit breaker, deenergize all control circuits to which it is connected; the procedure differs somewhat with the type of mounting which is employed. For example, before work is performed on drawout circuit


(1) BREAKER OPERATING HANDLE SHOWN IN TRIPPED POSITION
(2) AMPERE RATING MARKER
(3) BREAKER MOUNTING SCREWS
(4) COVER SCREWS
(5) CURRENT LIMITING FUSES
(6) FUSE UNIT ASSEMBLY
(7) FUSE UNIT INTERLOCK PIN
(8) TRIP LEVER
(9) FUSE SLIP-ON CONNECTORS
(10) FUSE RETAINING BLOCK SCREWS
(11) INSTANTANEOUS TRIP ADJUSTING WHEELS
3
4
4
1
11
2
8
11
7
4
4
9
9
3
9
3
6
5
10
10

77.247

Figure 3-39.—Complete circuit breaker, front view with fuse unit removed.

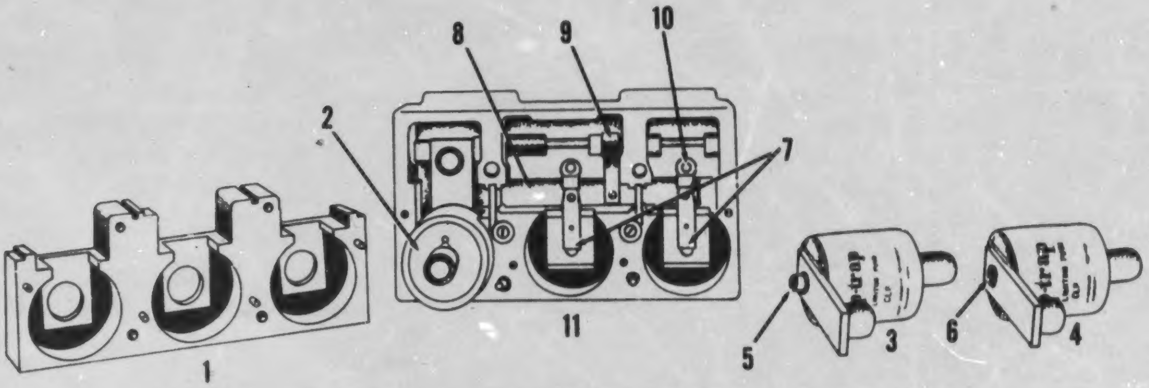
breakers, they should be switched to the open position and removed. Before working on fixed-mounted circuit breakers, open the disconnecting switches ahead of the breakers. If disconnecting switches are not provided for isolating fixed-mounted circuit breakers, deenergize the supply bus to the circuit breaker, if practicable, before inspecting, adjusting, replacing parts, or doing any work on the circuit breaker.

Contacts are the small metal parts especially selected to resist deterioration and wear from the inherent arcing. The arcing occurs in a circuit breaker while its contacts are opening and carrying current at the same time. When firmly closed, the contacts must not arc.

Contact materials have been subjected to constant research, resulting in various products, ranging from pure carbon or copper, to pure silver, each being used alone and also as alloys with other substances. Modern circuit breakers have contacts coated with silver, or silver mixed with cadmium oxide, or silver and tungsten. The two latter silver alloys are extremely hard and resist being filed. Fortunately, such contacts made of silver or its alloys conduct current when discolored (blackened during arcing) with silver oxide. The blackened condition, therefore, requires no filing, polishing, or removal. As with a silver contact, silver oxide is formed during arcing and it has been found that the addition of cadmium oxide greatly improves operation of the contact because it minimizes the tendency of one contact to weld to another, retards heavy transfer of one material to another, and inhibits erosion.

Usually, a contact containing silver is serviceable as long as the total thickness worn away does not exceed 0.030 inch.

Severe pitting or burning of a silver contact is another matter. It may require some filing (with a fine file or with fine sandpaper, No. 00) to remove raised places on surfaces that prevent intimate and overall closure of the contact surfaces. If necessary, use a CLEAN cloth moistened with INHIBITED methyl chloroform Be very certain to provide ample ventilation to remove all DEADLY and TOXIC fumes of the solvent.



(1) FUSE RETAINING BLOCK
(2, 3 & 4) CURRENT LIMITING FUSES
(5) EXTENDED PLUNGER OF BLOWN FUSE
(6) RETRACTED PLUGER OF UNBLOWN FUSE
(7) FUSE PLUNGER LEVER
(8) FUSE UNIT TRIPPER BAR
(9) FUSE UNIT TRIPPER BAR LEVER
(10) FUSE INTERLOCK PIN
(11) FUSE UNIT HOUSING

77.248

Figure 3-40.—Current limiting fuse unit assembly.

When cleaning and dressing copper contacts, maintain the original shape of each contact surface and remove as little copper metal as possible. Inspect and wipe the copper contact surfaces for removal of the black copper-oxide film and, in extreme cases, dress and clean only with fine (No. 00) sandpaper to prevent scratching the surfaces.

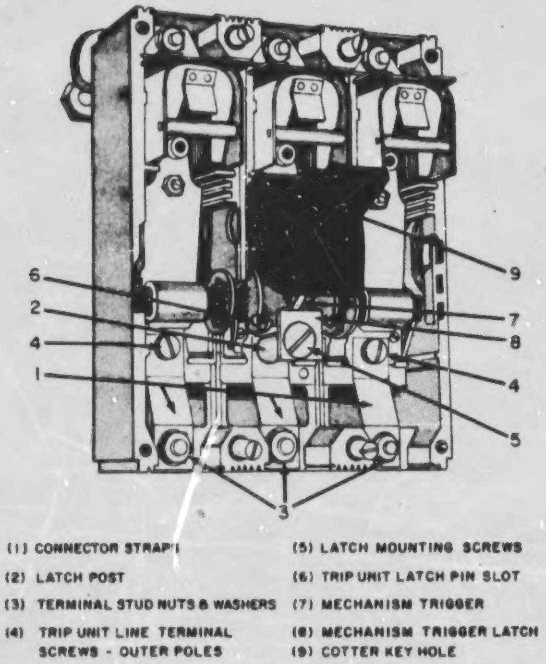
NEVER use emery cloth or emery paper. Because this copper-oxide film is a partial insulator, follow the sanding procedure by wiping with a clean cloth moistened with inhibited methyl chloroform solvent. Provide VERY LIBERAL ventilation by means of exhaust fans or with portable blowers to entirely remove all traces of the deadly fumes of the solvent.

Calibration problems on circuit breakers should be handled in accordance with chapter 9600 of NavShips Technical Manual.

The function of arcing contacts is not necessarily impaired by surface roughness. Remove excessively rough spots with a fine file. Replace arcing contacts when they have been burned severely and cannot be properly adjusted. Make a contact impression and check the spring pressure in accordance with the manufacturers' instructions. If information on the correct contact pressure is not available, the contact pressure should be checked with that of similar contacts. When the force is less than the designed value, the contacts either require replacing because they are worn down, or the contact springs should be replaced. Always replace contacts in sets; not singly, and replace contact screws at the same time. Do not use emery paper or emery cloth to clean contacts, and do not clean contacts when the equipment is energized.

Clean all surfaces of the circuit breaker mechanism, particularly the insulation surfaces, with a dry cloth or air hose. Before directing the air on the breaker, be certain that the water is blown out of the hose, that the air is dry, and that the pressure is not over 30 psi. Check the pins, bearings, latches, and all contact and mechanism springs for excessive wear or corrosion and evidence of overheating. Replace parts if necessary.

Slowly open and close circuit breakers manually a few times to be certain that trip shafts, toggle linkages, latches, and all other mechanical parts operate freely and without binding. Be certain that the arcing contacts make before and break after the main contacts. If poor alignment, sluggishness, or other abnormal conditions are noted, adjust in accordance with


6
2
4
1
9
7
8
4
5
3
(1) CONNECTOR STRAPS
(2) LATCH POST
(3) TERMINAL STUD NUTS & WASHERS
(4) TRIP UNIT LINE TERMINAL SCREWS - OUTER POLES
(5) LATCH MOUNTING SCREWS
(6) TRIP UNIT LATCH PIN SLOT
(7) MECHANISM TRIGGER
(8) MECHANISM TRIGGER LATCH
(9) COTTER KEY HOLE

77.249
Figure 3-41. — NQB-A250 circuit breaker front view, cover removed.

the manufacturer's instructions for the particular circuit breaker.

Before returning a circuit breaker to service, inspect all mechanical and electrical connections, including mounting bolts and screws, drawout disconnect devices, and control wiring. Tighten where necessary. Give the breaker a final cleaning with a cloth or compressed air. Operate manually to be certain that all moving parts function freely. Check the insulation resistance.

The sealing surfaces of circuit-breaker contactor and relay magnets should be kept clean and free from rust. Rust on the sealing surface decreases the contact force and may result in overheating of the contact tips. Loud humming or chattering will frequently warn of this condition. A light machine oil wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rust.

Oil should always be used sparingly on circuit breakers, contactors, motor controllers, relays, and other control equipment, and should not be used at all unless called for in the manufacturer's instructions or unless oil holes are provided. If working surfaces or bearings show signs of rust, disassemble the device and carefully clean the rusted surfaces. Light oil can be wiped on sparingly to prevent further rusting. Oil has a tendency to accumulate dust and grit, which may cause unsatisfactory operation of the device, particularly if the device is delicately balanced.

Arc chutes or boxes should be cleaned by scraping with a file if wiping with a cloth is not sufficient. Replace or provide new linings when they are broken or burned too deeply. Be certain that arc chutes are securely fastened and that there is sufficient clearance to ensure that no interference occurs when the switch or contact is opened or closed.

Shunts and flexible connectors, which are flexed by the motion of moving parts, should be replaced when worn, broken, or frayed.

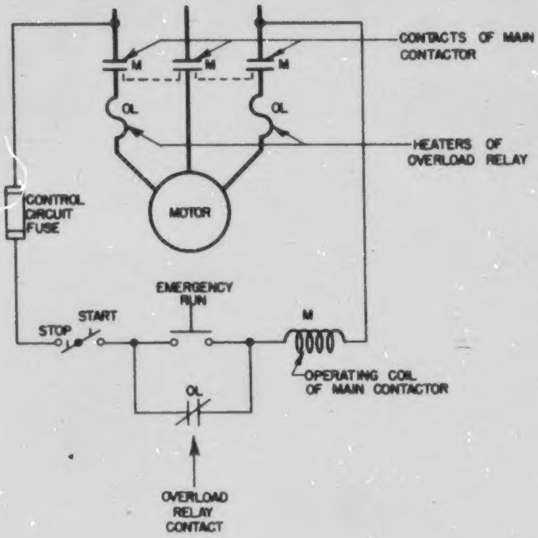
Operating tests that consists of operating the circuit breakers in the manner in which they are intended to function in service should be conducted regularly. For manually operated circuit breakers, simply open and close the breaker to check the mechanical operation. To check both the mechanical operation and the control wiring, electrically operated circuit breakers should be tested by means of the operating switch or control. Exercise care not to disrupt any electric power supply that is vital to the operation of the ship, or to endanger personnel by inadvertently starting motors and energizing equipment under repair.

OVERLOAD RELAYS

Overload relays are provided in motor controllers to protect the motor from excessive currents. Excessive motor current causes normally closed overload relay contacts to open which break the circuit to the operating coil of the main contactor, and disconnects the motor from the line (fig. 3-42). Overload relays are of the thermal or magnetic type.

Thermal Relay

The thermal overload relay has a heat-sensitive element and an overload heater connected in series with the motor circuit as shown in figure 3-42. When the motor current is excessive, heat from the heater causes the heat-sensitive element to open the overload relay contacts. As it takes time for the heat-sensitive


CONTACTS OF MAIN CONTACTOR
M
M
M
OL
OL
HEATERS OF OVERLOAD RELAY
CONTROL CIRCUIT FUSE
MOTOR
EMERGENCY RUN
START
STOP
M
OPERATING COIL OF MAIN CONTACTOR
OL
OVERLOAD RELAY CONTACT

124.249

Figure 3-42.—Schematic diagram of motor controller with thermal type overload.

element to heat up, the thermal type of overload relay has an inherent time delay. Thermal overload relays may be of the solder-pot, bimetal, single metal, or induction type.

SOLDER-POT TYPE.—The heat sensitive element is a solder pot which consists of a cylinder inside a hollow tube. These are normally held together by a film of solder. In case of excessive motor current, the heater melts the solder, breaks the bond between the tube and cylinder, and releases the tripping device of the relay. After the relay trips, the solder cools and soldifies, and the relay is ready to be reset.

BIMETAL TYPE.—The heat-sensitive element is a strip or coil of two different metals fused together along one side. When heated, one metal expands more than the other causing the strip or coil to bend or deflect, and open the overload relay contacts.

SINGLE METAL TYPE.—The heat-sensitive element is a metal tube around the heater. The tube lengthens when heated and opens the overload relay contacts.

INDUCTION TYPE.—The heat-sensitive element is usually a bimetal strip or coil. The heater cnsists of a coil in the motor circuit and a copper tube inside the coil. The copper tube acts as a short-circuited secondary of a transformer, and is heated by the current induced in it. This type of overload relay is used only in a-c controllers, whereas the previously described types of thermal overload relays may be used in a-c or d-c controllers.

Magnetic Relay

The magnetic overload relay has a coil connected in series with the motor circuit and a tripping armature or plunger. When the motor current is excessive, the armature opens the overload relay contacts. Magnetic overload relays may be of the instantaneous or time delay type.

INSTANTANEOUS TYPE.—This type operates instantaneously when the motor current becomes excessive. The relay must be set at a tripping current higher than the motor starting current to prevent ripping when the motor is started. This type of overload, relay is used mostly for motors that are started on reduced voltage then switched to full line voltage after the motor comes up to speed.

TIME DELAY TYPE.—This type is essentially the same as the instantaneous type with the addition of a time delay device. The time delay device may be an oil dashpot with a piston attached to the tripping armature of the relay. The piston has a hole through which oil passes when the tripping armature is moved due to excessive motor current. The size of the hole can be adjusted to change the speed at at which the piston moves for a given pull on the armature. For a given size hole, the larger the current, the faster the operation. This allows the motor to carry a small overload current for a longer period of time than a large overload current.

ELECTRICAL CABLES

Shipboard electrical and electronic systems require a large variety of electric cables. Some circuits require only a few conductors having a high current-carrying capacity; others require many conductors having a low current-carrying capacity; still others may require cables with a special type of insulation, the conductors may have to be shielded, or in some cases the conductors may have to be of a metal other than copper.

The proper installation and maintenance of the various electrical systems aboard ship are very important to the IC Electrician. The repair of battle damage, accomplishment of ship alterations, and some electrical repairs may require that changes or additions to the ship's cables, control and protective devices, be made by the IC gang. Additionally, during shipyard and tender availabilities, you may be required to inspect, test, and approve the new installations.

To perform these tasks you must first have a working knowledge of the various types, sizes, capacities, and uses of shipboard electrical cable. The IC Electrician must also be capable of selecting, installing, and maintaining cables in such a manner as to ensure their adequacy. Finally, you must know the purpose, construction, installation, and testing procedures of control and protective devices in order to maintain an electrical system properly.

CABLE COMPARISON GUIDE

The IC Electrician needs to have a working knowledge of the Cable Comparison Guide, NavShips 0981-052-8090. This guide fills a need for information on the use of electric shipboard cable, particularly for the selection of substitute cable items for replacement of obsolete items. Cable items are listed in the guide by general classifications as to construction and service conditions. These broad groupings are broken down into types and sizes and indicated as being current (C), discontinued (D), or obsolete (O), as shown in the first column of Table 3-1.

The term "watertight cable," designated by an asterisk (*) in the cable guide and in Table 3-1, indicates standard cables in which all spaces under the impervious sheath are filled with material to eliminate voids and to prevent the flow of water through the cable by hose action in the event that an open end of cable is exposed to water under pressure.

Because of the varied service conditions aboard ship, the cable must have the ability to withstand heat, cold, dampness, dryness, bending, crushing, vibration, twisting, and shock. No one type of cable has been designed to meet all of these requirements; therefore, a variety of types are employed in a shipboard cable installation.

Cable types are grouped under the general classifications of: (1) cables for nonflexing service (table 3-1), (2) cables for repeated flexing service, and (3) cables for special purposes.

Table 3-1. —Cables for Nonflexing Service

Cur Dis Obs	Type & Size	No of Cdrs	Strands Per Cdr	Diam Copper Cdr Inch	Area Cdr Cirmils	Outside Diam Cable Max Inch	Stuffing Tube Size		Maximum Rating			Min Radius of Bend Inch	Est Wt Per Ft Lbs.	Federal Stock No GX6145
							Deck and Bulkhead	Equipment	Voltage Volts rms	Ambient Temperature 40°C Amperes	50°C			
					LIGHTING AND POWER – Cont.									
C	DSGA-400*	2	127	.742	413,600	2.119	V	8	1000	492	453	13.0	4.28	184-5897
D	DHFA-400*	2	127	.742	413,600	2.508	Y	9	600	492	453	15.5	4.75	192-7195
O	DHFA-400	2	127	.742	413,600	2.508	Y	9	600	492	453	15.5	4.75	192-7221
C	6SGA-150*	6	61	.457	157,600	2.010	T	8	1000	326	300	12.0	4.17	
C	6SGA-200*	6	61	.514	198,700	2.250	W	9	1000	369	340	13.5	5.19	

Maximum ratings for 6SGA cables are for 400 hertz power circuits only.

*Watertight Construction

77.1

CABLE TYPE AND SIZE DESIGNATIONS

Shipboard electrical cables are identified according to type and size. Type designations consist of letters to indicate construction and/or use. Size designations consists of a number or numbers to indicate the size of the conductor(s) in circular mil area, number of conductors, or number of pairs of conductors depending upon the type of cable.

In most cases the number of conductors in a cable, up to and including four conductors, is indicated by the first type letter as follows: S-single conductor; D-double conductor; T-three conductor; and F-four conductor. For cables with more than four conductors, the number of conductors is usually indicated by a number following the type letters. In this latter case, the letter M is used to indicate Multiple Conductor. Examples of common shipboard cable designations are as follows:

DSGA-3-Double conductor, Shipboard, General use, Armored, conductor size approximately 3000 circular mils.

FHFA-4-Four conductor, Heat and Flame resistant, Armored, conductor size approximately 4000 circular mils. Type HFA cable has been replaced by type SGA.

DCOP-2-Double conductor, Oil resistant, Portable conductor, size approximately 2000 circular mils.

MSCA-30-Multiple conductor, Shipboard, Control, Armored, with 30 conductors.

MDGA-19 (6)-Multiple conductor, Degaussing, Armored, 19 conductors, conductor size approximately 6000 circular mils.

Also included in this lighting and power group is the DSGA type cable. The DSG type cable employs silicone rubber and glass as primary insulation, making it heat and flame resistant.

The construction of a DSGA cable is shown in figure 3-43. The insulated stranded copper conductors are enclosed in an impervious sheath, braided metal armor, and paint. The cable has been made watertight by the application of waterproof sealing compound to all voids of the conductors and cable core. DSGA cables are designed to have a minimum outside diameter and weight as compared to older type cable. Using the newer cable saves on space and weight which is at a premium on combatant naval vessels.

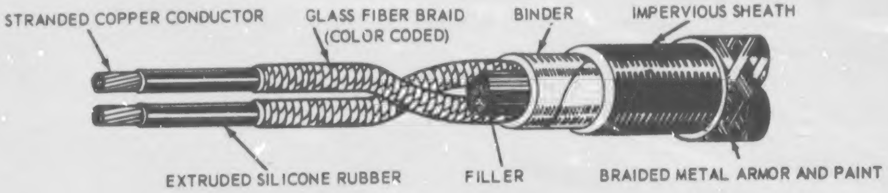
The numerals (table 3-1) immediately following the type letters indicate the cross-sectional area of a single conductor and expressed in thousands of circular mils. For example, 6SGA-150 indicates approximately 158 thousand circular mils conducting area.

Table 3-1 also lists the sizes of stuffing tubes (metal or plastic tubing containing the cable) used with particular types and sizes of cable. Metal stuffing tubes are used generally for deck and bulkhead installations.

Type and Size Exceptions

By analyzing the designations for cable types and sizes, you will notice that some letters have more than one meaning. The letter T, for example, usually means THREE. In the designation TTHFWA-10, however, the double T stands for twisted-pair, telephone. The T in TRXF means tough jacket.

Similarly, there are exceptions regarding the use of numerals in size designations since the numerals may indicate number of copper conductors or size of copper conductor or number and size of a conductor or size and number of


STRANDED COPPER CONDUCTOR
GLASS FIBER BRAID (COLOR CODED)
BINDER
IMPERVIOUS SHEATH
EXTRUDED SILICONE RUBBER
FILLER
BRAIDED METAL ARMOR AND PAINT

29.226(77)A

Figure 3-43.—Type DSGA shipboard nonflexing service cable.

strands per conductor or number of twisted pairs or maximum rms rated voltage.

Example: MSCA-7 — The 7 stands for the number of conductors, not the conductor area as in the case of DHFA-400 (table 3-1).

Example: TTHFWA-10 — The 10 indicates the number of twisted pairs; that is, 20 conductors.

Example: SS5P — The 5 is an indication of maximum rms rated voltage, 5000 in this case.

NONFLEXING SERVICE

Nonflexing service cable designed for use aboard ship is intended for permanent installation and is commonly referred to as such. The cables that are described in the previous paragraphs for use with lighting and power circuits are intended for this nonflexing service. This nonflexing service can be further classified according to its application and is of two types — general use and special use.

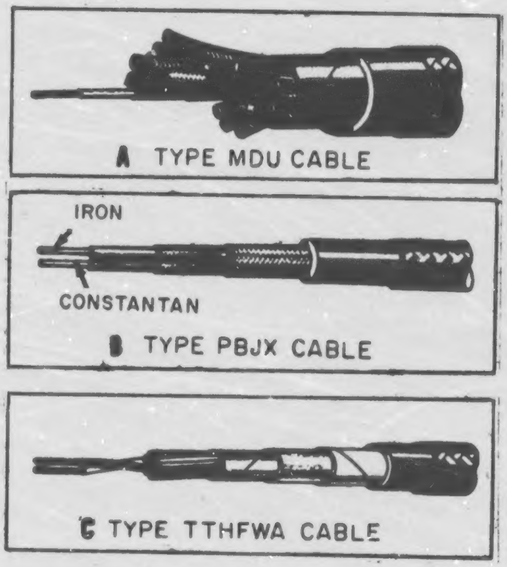
General Use (Nonflexing Service)

Nonflexing service cable is intended for use in nearly all portions of electric distribution systems, including the common telephone circuits and most propulsion circuits. Special cases occur in d-c propulsion circuits for surface ships. In those cases where the impressed voltage is less than 1000 volts, an exception is permitted.

The previously described DSGA cable is one type usually found in this general use, nonflexing service. Also in this classification is the type MSCA cable. This cable is nothing more than watertight cable for use in interior communications, as well as in fire control circuits.

Special Use (Nonflexing Service)

There are many shipboard electrical circuits where special requirements of voltage, current, frequency and service must be met in the cable installation and other circuits where general use, nonflexing service cable may meet the necessary requirements, yet be economically impracticable. For these reasons, there are many different types of nonflexing service cable for specialized use, such as degaussing, telephone radio, and casualty power. Some of these cables are shown in figure 3-44.

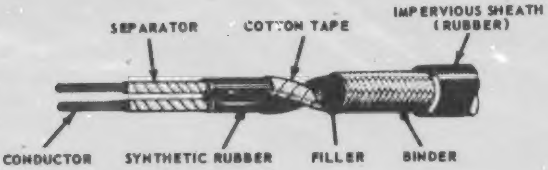


29.226(77A)B
Figure 3-44. — Nonflexing service cable for special use.

Type MDU (fig. 3-44A) is a multiconductor cable used in degaussing circuits. Type PBJX (replaced by type TCJA-mil-C-2194 on new construction) cable (fig. 3-44B) consists of one conductor of constantan (red) and one conductor of iron (gray), and is used for pyrometer base leads. Type TTHFWA (fig. 3-44C) is a multiconductor, twisted-pair cable used for telephone circuits.

REPEATED FLEXING SERVICE

Repeated flexing service cable designed for use aboard ship is commonly referred to as



29.226(77)C

Figure 3-45.—Type DHOF shipboard repeated flexing service cable.

being portable because it is principally used as leads to portable electric equipment. It is also of two types—general use and special use.

General Use (Flexing Service)

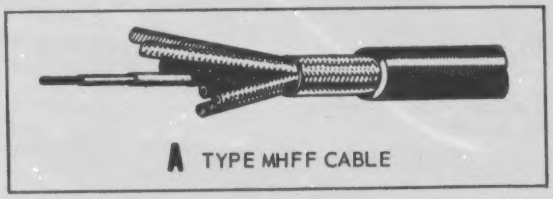
Repeated flexing service cable is designed for use as leads to portable equipment and permanently installed equipment where cables are subjected to repeated bending, twisting, mechanical abrasion, oil, sunlight, or where maximum resistance to moisutre is required. Its letter designation is HOF (heat and oil resistant, flexible). This cable contains stranded copper conductors that are insulated with butyl rubber, covered with a tape or braid. The designated number of conductors are twisted together, held by a binder, and covered with an impervious sheath (fig. 3-45).

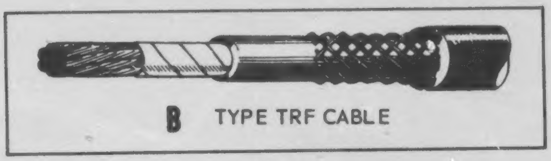
Repeated flexing service cable designed for general use is of four different types, depending on the number of conductors. Type SHOF cable is available in various conductor sizes and designated as types SHOF (single conductor), DHOF (two conductor), THOF (three conductor), and FHOF (four conductor).

Special Use (Flexing Service)

There are many different types of repeating flexing service cable designed for special requirements of certain installations, including type TTOP and casualty power cables. Two of these types are shown in figure 3-46 type MHFF, (fig. 3-46A) is used for control circuits in revolving structures, and type TRF (fig. 3-46B) is used for arc-welding circuits.

COLOR CODES


A TYPE MHFF CABLE


B TYPE TRF CABLE

29.226(77)D

Figure 3-46.—Repeated flexing service cable for special use.

The color code given in table 3-2 applies to all multiple conductor (except twisted-pair or 3-conductor commercial for portable tools and equipment) cables having from 2 to 44 individually insulated conductors within a common protective sheath. For example, all single- conductor cables are black; all 2-conductor cables consist of 1 black, 1 white, and all 3-conductor cables consist of 1 black, 1 white, and 1 red, etc., up to a 44-conductor cable, where all the color combinations listed in table 3-2 would be included. In cables with more than one layer of conductors, the numbering shown in the table is from the innermost to the outmost. For example, the No. 1 conductor will be the center conductor (or one of the center conductors where two or more are used as a center) of the concentric lay. The color coding of 3-conductor flexible cable for single-phase a-c and 2-wire d-c portable equipment and tools is black, white, and green. The green conductor is used to ground the metal case of the equipment to the ship's hull.

Individual conductors and pairs in twisted-pair telephone cables are color coded by pairing the solid colors in sequence as shown in table 3-3.

CABLE MARKING

Ready identification for maintenance and repairs of IC circuits is provided by cable designations embossed on the cable tags (fig. 3-47). These cable designations include (1) service letter, (2) circuit letter(s), and (3) cable number. The SERVICE is denoted by the letter C, which is the designation for all cables and circuits that comprise the IC system in naval ships. Each circuit is distinguished by a single letter or

Table 3-2. —Color Coding of Multiple Conductors Cables

Conductor No.	Base color	Tracer color	Tracer color
1	Black		
2	White		
3	Red		
4	Green		
5	Orange		
6	Blue		
7	White	Black	
8	Red	"	
9	Green	"	
10	Orange	"	
11	Blue	"	
12	Black	White	
13	Red	"	
14	Green	"	
15	Blue	"	
16	Black	Red	
17	White	"	
18	Orange	"	
19	Blue	"	
20	Red	Green	
21	Orange	"	
22	Black	White	Red
23	White	Black	"
24	Red	"	White
25	Green	"	"
26	Orange	"	"
27	Blue	"	"
28	Black	Red	Green
29	White	"	"
30	Red	Black	"
31	Green	"	Orange
32	Orange	"	Green
33	Blue	White	Orange
34	Black	"	"
35	White	Red	"
36	Orange	White	Blue
37	White	Red	"
38	Brown		
39	"	Black	
40	"	White	
41	"	Red	
42	"	Green	
43	"	Orange	
44	"	Blue	

140.64

double letters. These letters identify the cable as a part of one of the numerous IC circuits. If two or more circuits of the same system are contained in a single cable, the number preceding the circuit letter or letters is omitted. The cable number is the number of the cable of the particular circuit.

Table 3-3.—Color Coding of Twisted Pair Telephone Cable

Telephone Pair	One Wire	Other Wire
1	White	Black
2	Red	Black
3	Green	Black
4	Orange	Black
5	Blue	Black
6	Brown	Black
7	Gray	Black
8	Yellow	Black
9	Purple	Black
10	Tan	Black
11	Pink	Black
12	Red	White
13	Green	White
14	Orange	White
15	Blue	White
16	Brown	White
17	Gray	White
18	Yellow	White
19	Purple	White
20	Tan	White
21	Pink	White
22	Green	Red
23	Orange	Red
24	Blue	Red

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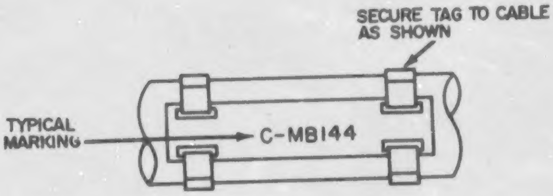

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Figure 3-47.—Cable tag.

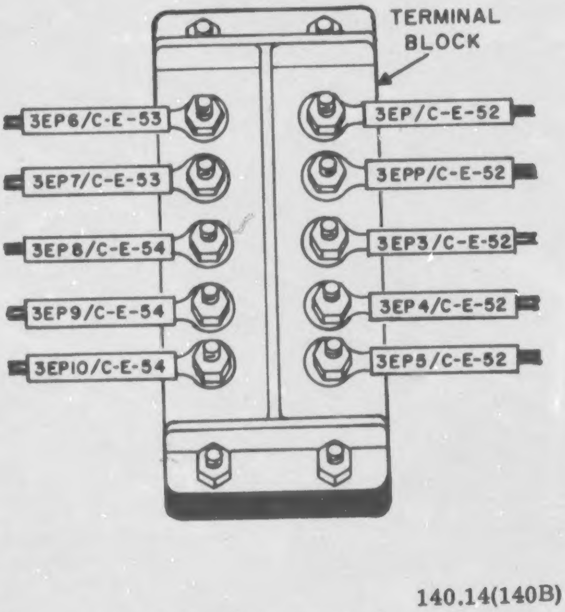
A typical cable designation is C-MD-144. The letter C denotes the service (the IC system). The letters MB denote the circuit, engine-order system, which may actually include wires of circuits 1MB, 2MB, 3MB, etc. The number 144 denotes cable number 144 of circuit MB.

Permanetly installed ships' cables are tagged as close as practicable to each point of connection, on both sides of decks, bulkheads, and other barriers. Cables located within a single compartment in such a manner that they can be readily traced are not tagged.

TERMINAL MARKING

In single-letter circuits and d-c supply circuits the positive terminal is designated by a single letter, as M. Similarly, an arbitrary polarity of single phase a-c circuits is designated by a single letter, as M (assumed instantaneous positive). The other side (representing the opposite polarity) of both d-c and a-c circuits is designated by the double letter, as MM.

Double-letter circuits have supply lead markings assigned as for single letter circuits, except that the second letter of the negative is doubled; for example, positive MB, negative MBB.



140.14(140B)

Figure 3-48.—Wire terminal markings.

All IC terminals are identified by insulated sleeving that is stamped with the lead number and cable number the lead belongs to (fig. 3-48).

The wire terminals 3EP and 3EPP, respectively, are the positive and negative supply terminals from cable C-E-52, which emanates from the IC switchboard and leaves from cable C-E-53. The wire terminals, 3EP3, 3EP5, 3DP6, and 3EP8, from cable C-E-52 are the positive terminals of pushbutton stations 3, 5, 6, and 8, respectively. The functions of these wires are found on the elementary and isometric drawings of the 3EP (protected E call) circuit for your ship.

Numbers following the circuit letter indicate a serial number assigned for the station, followed by the section wire number designating the function of the circuit. On systems containing synchros, the numberals, 1, 2, and 3, are used for the connections to secondary windings. Where more than one synchro is employed in a single instrument, the numberals 4, 5, and 6, apply to the second synchro, and 7, 8, and 9 to the third synchro. For example, 1-MB14 should be interpreted as follows:

1—starboard circuit
MB-engine-order system
1—station number, such as pilot house
4—connection to secondary windings of the No. 2 synchro receiver in the instrument

If corresponding portions of a circuit are energized from the forward and aft IC switchboards, the suffix letters, F and A, are added to the ends of wire markings to indicate the switchboard from which the wire originated.

All terminals in a circuit that may be connected without a break (in the electrical sense) shall be assigned the same wire marking. A fuse, switch, or instrument is considered a break in the circuit and requires a change in the wire marking.

Signal contacts should be connected to the positive (single-letter connection) in the instruments. The section-wire markings for bell or visual signal circuits should be assigned the next higher number after assignment of numbers to secondary windings of all synchro receivers in the instruments. For example, in an instrument containing two synchro receivers the signal circuits should be assigned section wires No. 7, 8, etc.

CABLE MAINTENANCE

The purpose of cable maintenance is to keep the cable insulation resistance high. Cables should be kept clean and dry, and protected from mechanical damage, oil, and salt water.

Testing Cables

Insulation resistance tests (ground tests) must be made periodically on IC cables to determine the condition of the cable. In addition, tests should be made when cables have been damaged, when cables have been disconnected for circuit or equipment changes, when there is evidence that a cable has been subjected to oil or salt water, and after shipboard overhauls.

Interior communication cables may be tested with a 500-volt megger if they are disconnected at the equipment or load end. In some cases, when it is not practical to disconnect the cable, an ohmmeter, or 50-volt tester must be used as described in NavShips Technical Manual, chapter 9650.

GROUND TESTS.—To ground test a multiconductor IC cable, proceed as follows:

1. Check to see that the cable armor is grounded by measuring between the cable armor and the metal structure of the ship; normally, grounding has been accomplished by means of cable straps. If a zero reading is not obtained, ground the cable armor.
2. Select one conductor to be tested, and connect all other conductors in the cable together and ground them by means of temporary wires or jumpers.
3. Measure the resistance of the conductor being tested to ground. The test voltage should be applied until a constant reading is obtained. Hand-driven generator type meggers should be cranked for at least 30 seconds to ensure a steady reading.
4. Repeat steps 2 and 3 as necessary to test each conductor to ground.

A reading equal to, or above the accepted minimum for the cable concerned (discussed later), indicates that the conductor under test is satisfactory. A reading below the accepted minimum indicates that the insulation resistance of the conductor under test to ground, or from one or more of the grounded conductors, or both, is low. The grounded conductors must then be disconnected from ground, and each conductor tested individually to isolate the low reading conductor(s).

An alternate method of ground testing multiconductor cables is to connect all conductors together and measure the insulation resistance from all conductors to ground simultaneously. If this reading is equal to or above the accepted minimum, no other reading need be taken. If the reading is below the accepted minimum, the conductors must be separated and tested individually to isolate the low reading conductor(s).

Factors Affecting Insulation Resistance

Factors that affect cable insulation resistance measurements are the length, type, temperature, and the equipment connect in the circuit. Each of these factors must be evaluated to reliably determine the condition of the cable from the measurements obtained.

LENGTH OF CABLE.—The insulation resistance of a length of cable is the resultant of a number of small individual leakage paths or resistances between the conductor and the cable sheath. These leakage paths are distributed along the cable. Hence, the longer the cable, the greater the number of leakage paths and the lower the insulation resistance. For example, if one leakage path exists in each foot of cable, there will be 10 such paths for current to flow between the conductor and the sheath in 10 feet of cable, and the total amount of current flowing in all of them would be 10 times as great as that which would flow if the cable were only 1 foot long. Therefore, to establish a common unit of comparison, cable-insulation resistance should be expressed in megohms (or ohms) per foot of length. This is determined by multiplying the measured insulation resistance of the cable by its total length in feet.

When measured insulation resistance is converted to insulation resistance per foot, the total length of cable to be used is equal to the length of the cable sheath for single conductor cable and for multiple conductor cable in which each conductor is used in one leg of a circuit. For example, in a TSGA cable with a cable sheath of 100 feet in which the three conductors are phases A, B, and C of a 3-phase power circuit, the total length of the cable is 100 feet, not 300 feet. The reason for this is that each conductor is measured separately. If this cable is connected, either in series or parallel, to a similar cable that has a sheath length of 400 feet, the total length is 500 feet. As another example, 200 feet of type MSCA-7 cable (7-conductor cable) connected to 200 feet of MSCA-24 cable (24-conductor cable) represents a total cable length of 400 feet.

TYPE OF CABLE.—Insulation resistance will vary considerably with the nature of the insulating materials employed and the construction of the cable. Therefore, it is possible to determine the condition of a cable by its insulation resistance measurements only when they are considered in relation to the typical characteristics of the particular type of cable. The minimum safe insulation resistance for types DSGA, HF, DG, SCA, TTHFA, and TTHFWA cables is indicated on the reverse side of the Resistance Test Record Card, NavShips 531-1, (fig. 3-49).

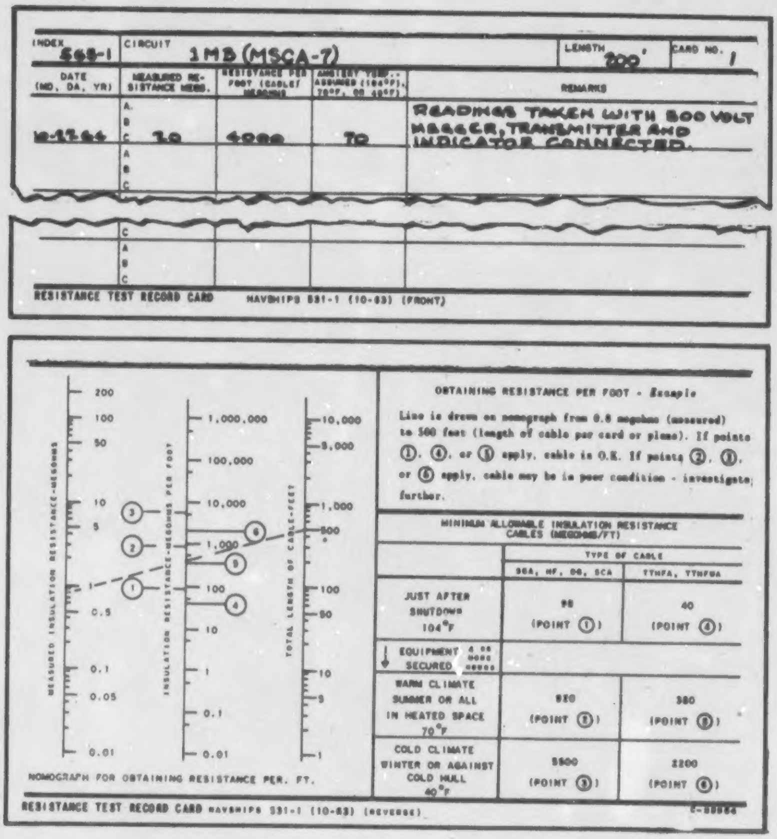
TEMPERATURE OF CABLE.—With nonflexing service cables, the highest permissible operating temperature (85° C at the sheath) and the nature of the insulating material makes it essential that temperature of the cable be considered in conjunction with the insulation resistance measurements. Therefore, fairly accurate estimates or measurements of the temperature of the sheath of the cable must be made to permit proper use of the Resistance Test Record Card.

EQUIPMENT CONNECTED.—When insulation resistance measurements are made with equipment connected, always record the exact equipment included, and the type of tester used, so that accurate comparisons can be made with similar past or future measurements.

CABLE REPAIR AND INSTALLATION

Electrical cables installed aboard Navy vessels must meet certain requirements determined by the Naval Ships Systems Command. These requirements, published in the General Specifications for Ships of the U. S. Navy, are too numerous to cover in detail in this training manual; hence, only the more basic ones are included.

The job of installing nonflexing service cable may be performed by the IC gang whenever necessary to repair damage or to accomplish authorized ship alterations. Before work is begun on a new cable installation, cableway plans should be available. If repairs to a damaged section of installed cable are to be effected, information on the original installation can be obtained from the plans of the ship's



INDEX 565-1	CIRCUIT 1MB (MSCA-7)		LENGTH 200'	CARD NO. 1
DATE (MO, DA, YR)	MEASURED RESISTANCE MEGS.	RESISTANCE PER FOOT (CABLE) MEGOHMS	AMBIENT TEMP. ASSUMED (104°F), 70°F, OR 40°F)	REMARKS
10-17-64	A B C 30	4000	70	READINGS TAKEN WITH 500 VOLT MEGGER, TRANSMITTER AND INDICATOR CONNECTED.
	A B C			
	C			
	A B C			

RESISTANCE TEST RECORD CARD NAVSHIPS 531-1 (10-63) (FRONT)

200
100
50
10
5
1
0.5
0.1
0.05
0.01
MEASURED INSULATION RESISTANCE-MEGOHMS
1,000,000
100,000
10,000
1,000
100
10
1
0.1
0.01
INSULATION RESISTANCE-MEGOHMS PER FOOT
10,000
5,000
1,000
500
100
50
10
5
1
TOTAL LENGTH OF CABLE-FEET
③
②
①
⑥
⑤
④

NOMOGRAPH FOR OBTAINING RESISTANCE PER. FT.

OBTAINING RESISTANCE PER FOOT - *Example*

Line is drawn on nomograph from 0.8 megohms (measured) to 500 feet (length of cable per card or plans). If points ①, ④, or ⑤ apply, cable is O.K. If points ②, ③, or ⑥ apply, cable may be in poor condition - investigate further.

MINIMUM ALLOWABLE INSULATION RESISTANCE CABLES (MEGOHMS/FT)

	TYPE OF CABLE	
	SGA, HF, DG, SCA	TTHFA, TTHFWA
JUST AFTER SHUTDOWN 104°F	95 (POINT ①)	40 (POINT ④)
EQUIPMENT SECURED		
WARM CLIMATE SUMMER OR ALL IN HEATED SPACE 70°F	520 (POINT ②)	380 (POINT ⑤)
COLD CLIMATE WINTER OR AGAINST COLD HULL 40°F	5500 (POINT ③)	2200 (POINT ⑥)

RESISTANCE TEST RECORD CARD NAVSHIPS 531-1 (10-63) (REVERSE)

Figure 3-49 —Resistance test record card. 1.3

electrical system, which are normally on file in the engineering department office (log room) aboard ship. If a ship alteration is to be accomplished, applicable plans not already on board, can be obtained from the naval shipyard listed on the authorization for the alteration (SHIPALT) at the planning yard for the ship.

Wireways

Before installing new cable, survey the area to see if there are spare cables in existing wireways and spare stuffing tubes that can be used in the new installation. The cable run must be located so that damage from battle will be minimized, physical and electrical interference with other equipment and cables will be avoided, and maximum dissipation of internally generated heat will occur. Do not run cables on the exterior of the deckhouse or similar structures above the main deck, except where necessary because of the location of the equipment served, or because of structural interferences or avoidance of hazardous conditions or locations. Where practicable, route vital cables along the inboard side of beams or other structural members to afford maximum protection against damage by flying splinters or machine gun strafing.

Where practicable, avoid installing cable in locations subject to excessive heat, and never install cable adjacent to machinery, piping, or other hot surfaces having an exposed surface temperature greater than 150° F. In general, cables shall not be installed where they may be subjected to excessive moisture.

Selecting Cable

When installing cable, use all reference data available. Table 3-4 is a typical cable characteristics chart for TTRSA, while table 3-5

Table 3-4.—Cable Characteristics

CABLE TYPE: **TTRSA**

USE: **Telephone and RF, Non-Flexing Service.**

DESCRIPTION: **Twisted shielded pair, radio, armored. Conductor insulation: Polythene over each conductor with an inner cotton braid over a braided copper shield on each pair. Cable insulation: Braided metal armor of aluminum alloy over an impervious sheath.**

CABLE SIZE DESIGNATION	NUMBER OF CONDUCTORS	STRANDS PER CONDUCTOR	C.M. AREA OF CONDUCTOR	DIAMETER OF CONDUCTOR	CABLE DIAMETER (OUTSIDE)	MAXIMUM RATING 50° C	
NO.	NO.	NO.	C.M.	INCH	INCH	VRMS	AMPS
2	4	7	1119	0.038	0.740	300	----
4	8	7	1119	0.038	0.800	300	----
6	12	7	1119	0.038	0.940	300	----
8	16	7	1119	0.038	1.050	300	----
10	20	7	1119	0.038	1.140	300	----
12	24	7	1119	0.038	1.160	300	----
16	32	7	1119	0.038	1.250	300	----

140.61

is an installation data chart from EIMB. Additional information is available in NavShips 0967-000-0110 Section 4, Interconnection Cabling and Wiring.

Stuffing Tubes

Stuffing tubes (fig. 3-50A, B, and C) are used to provide for the entry of electric cable into splashproof, spraytight, submersible, and explosion-proof equipment enclosures. Cable clamps, commonly called box connectors (shown in figure 3-51), may be used for cable entry into all other types of equipment enclosures, except that top entry into these enclosures shall be made dripproof through stuffing tubes or cable clamps sealed with plastic sealer.

Below the main deck, stuffing tubes are used for cable penetrations of watertight decks, watertight bulkheads, and watertight portions of bulkheads that are watertight only to a certain height. Above the main deck, stuffing tubes are used for cable penetrations of (1) watertight or airtight boundaries; (2) bulkheads designed to withstand a waterhead; (3) that portion of bulkheads below the height of the sill or coaming of compartment accesses; (4) flametight or gastight, or watertight bulkheads, decks, or wiring trunks within turrets or gun mounts; and (5) structures subject to sprinkling.

Table 3-5. —Installation Data

CABLE TYPE: **TTRSA**

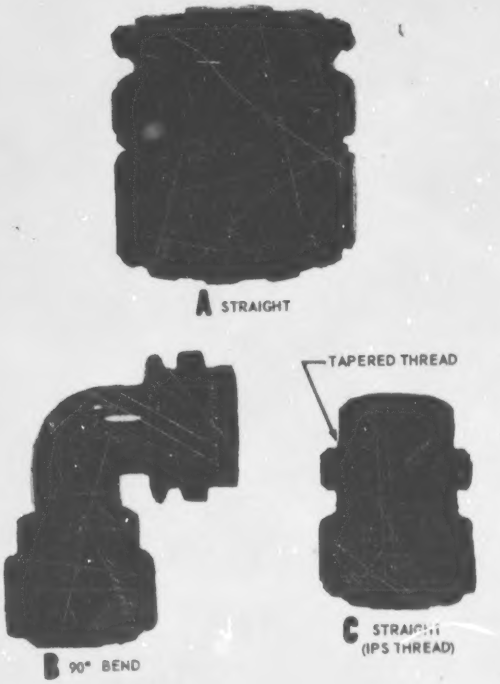
USE: **Telephone and RF, Non-Flexing Service.**

DESCRIPTION: **Twisted shielded pair, radio, armored. Conductor insulation: Polythene over each conductor with an inner cotton braid over a braided copper shield on each pair. Cable insulation: Braided metal armor of aluminum alloy over an impervious sheath.**

CABLE SIZE DESIGNATION	BEND RADIUS (MINIMUM)	METAL TUBE SIZE	BOX CONNECTOR SIZE	NYLON TUBE SIZE	NYLON TUBE PACKING ASSEMBLY	SYNTHETIC RUBBER GROMMET	KICKPIPE SIZE
NO.	INCH	NO.	INCH	NO.	MS NO.	INCH	INCH
2	5.0	E	3/4	4	16179-5	3/4	1
4	5.0	F	1S	4	16179-7	3/4	1
6	6.0	J	1S	5	16189-3	1	1-1/4
8	6.5	K	1-1/4	5	16189-4	1	1-1/4
10	7.0	K	1-1/4	5	16189-7	1-1/4	1-1/4
12	7.0	L	1-1/4	5	16189-8	1-1/4	1-1/4
16	7.5	M	1-1/4	6	16190-1	1-1/4	1-1/2

140.62

Stuffing tubes are made of nylon, steel, brass, or aluminum alloys. Nylon tubes have very nearly replaced metal tubes for cable entry to equipment enclosures. Cable penetration of bulkheads and decks using nylon stuffing tubes is limited for use above the watertight level of a vessel. The watertight level is the highest expected water level (determined by the Naval Ship Systems Command studies of stability and reserve buoyancy) and is indicated on the applicable ship's plans. The nylon tube is a lightweight, positive-sealing, noncorrosive stuffing tube, which requires only minimum maintenance for the preservation of watertight integrity (fig. 3-52). The watertight seal between the entrance to the enclosure and nylon body of the stuffing tube is made with a neoprene "O" ring, which is compressed by a nylon locknut. A grommet type, neoprine packing is compressed by a nylon cap to accomplish a watertight seal between the body of the tube and the cable. Two slip washers act as compression washers on the grommet as the nylon cap of the stuffing tube is tightened. Grommets of the same external size, but with different sized holes for the cable, are available. This allows a single-size stuffing tube to be used for a variety of cable sizes, and makes it possible for nine sizes of nylon tubes to replace 23 sizes of aluminum, steel, and brass tubes.



12.78

Figure 3-50. —Nylon stuffing tubes.

The nylon stuffing tube is available in two parts. The body "O" ring, locknut, and cap comprise the tube; and the rubber grommet, two slip washers, and one bottom washer comprise the packing kit.

A nylon stuffing tube that provides cable entry into an equipment enclosure is applicable to both watertight and nonwatertight enclosures (fig. 3-52A). Note that the tube body is inserted from inside the enclosure. The end of the cable armor, which will pass through the slip washers, is wrapped with friction tape to a maximum diameter. To ensure a watertight seal, one coat of neoprene cement is applied to the inner surface of the rubber grommet and to the cable sheath where it will contact the grommet. After the cement is applied, the grommet is immediately slipped onto the cable. The paint must be cleaned from the surface of the cable sheath before applying the cement.

Sealing plugs are available for sealing nylon stuffing tubes from which the cables have been removed. The solid plug is inserted in place of the grommet, but the slip washers are left in the tube (fig. 3-52B).

A grounded installation that provides for cable entry into an enclosure equipped with a nylon stuffing tube is shown in figure 3-53. This type of installation is required only when radio interference tests indicate that additional grounding is necessary within electronic spaces. In this case, the cable armor is flared and trimmed to the outside diameter of the slip washers. One end of the ground strap is inserted through the cap, and one washer is flared and trimmed to the outside diameter of the washers. Contact between the armor and the strap is maintained by pressure of the cap on the slip washers and the rubber grommet.

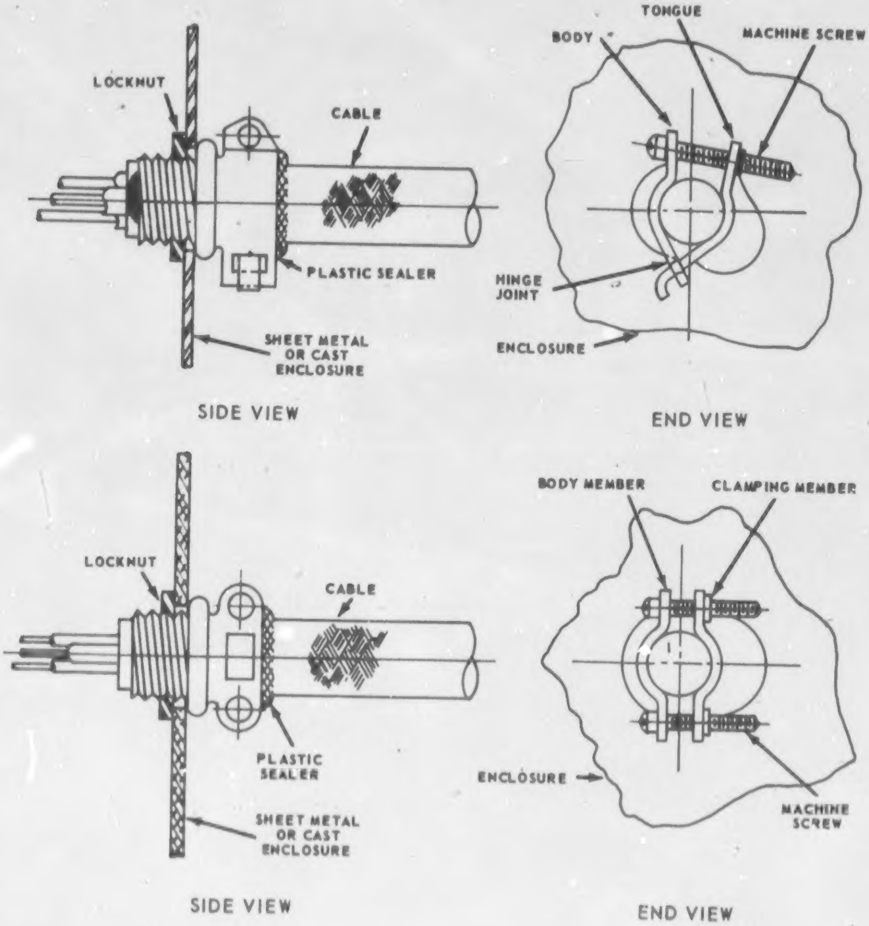
Tables listing the correct size for deck, bulkhead, and equipment stuffing tubes for lighting and power cables are found in the Cable Comparison Guide, NavShips 0981-052-8090.

Watertight integrity is vital aboard ship in peacetime or in combat. Just one improper cable installation could endanger the entire ship. For example, if one THFA-4 cable (.812 inches in diameter) is replaced by the newer TSGA-4 cable (.449 inches in diameter) but the fittings passing through a watertight bulkhead are not changed to the proper size, the result could be two flooded spaces in the event of a collision or enemy hit.

Deck Risers

Where one or two cables pass through a deck in a single group, kickpipes are provided to protect the cables against mechanical damage. Steel pipes are used with steel decks, and aluminum pipes with aluminum and wooden decks. NOTE: When stuffing tubes and kickpipes are installed, care must be taken not to install two different metals together, an electrolytic action may be set up. Inside edges on the ends of the pipe and the inside wall of the pipe must be free of burrs to prevent chafing of the cable. Kickpipes including the stuffing tube shall have a minimum height of 9 inches and a maximum of 18 inches. Where the height exceeds 12 inches, a brace is necessary to ensure rigid support. Where the installation of kickpipes is required in nonwatertight decks, a conduit bushing may be used in place of the stuffing tube.

When three or more cables pass through a deck in a single group, riser boxes must be used


LOCKNUT
CABLE
PLASTIC SEALER
SHEET METAL OR CAST ENCLOSURE
SIDE VIEW
BODY
TONGUE
MACHINE SCREW
HINGE JOINT
ENCLOSURE
END VIEW
LOCKNUT
CABLE
PLASTIC SEALER
SHEET METAL OR CAST ENCLOSURE
SIDE VIEW
BODY MEMBER
CLAMPING MEMBER
ENCLOSURE
MACHINE SCREW
END VIEW

77.8

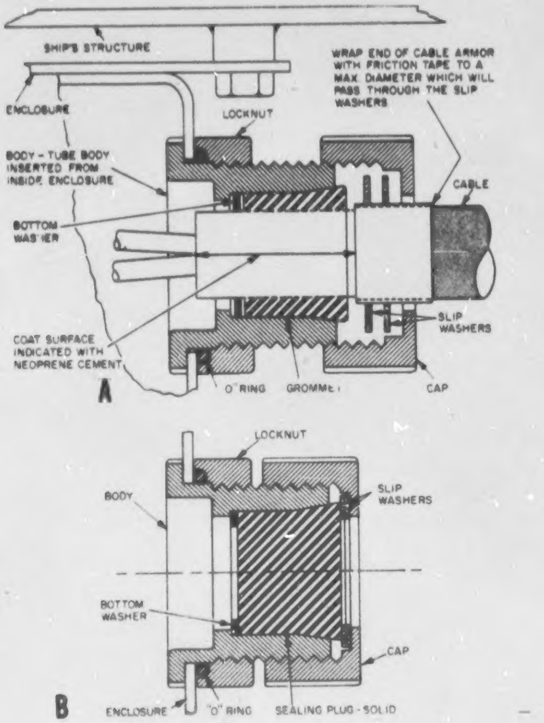
Figure 3-51.—Cable clamps.

to provide protection against mechanical damage. Stuffing tubes are mounted in the top of riser boxes required for topside weatherdeck applications. For cable passage through watertight decks inside a vessel the riser box may cover the stuffing tubes if it is fitted with an access plate of expanded metal or perforated sheet metal. Stuffing tubes are not required with riser boxes for cable passage through nonwatertight decks.

Cable Supports

The single cable strap is the simplest form of cable support. The cable strap is used to secure cables to bulkheads, decks, cable hangers, fixtures, etc. (fig. 3-54). The one-hole cable strap (fig. 3-54A) may be used for cables not exceeding five-eighths of an inch in diameter. The two-hole strap (fig. 3-54B) may be used for cables over five-eighths of an inch in diameter. The spacing of simple cable supports, such as those shown in figure 3-54 must not exceed 32 inches center to center. A more complex cable support is the cable rack, which consists of the cable hanger, cable strap, and hanger support (fig. 3-55).

Banding material is five-eighths of an inch wide, and may be zinc-plated steel, corrosion

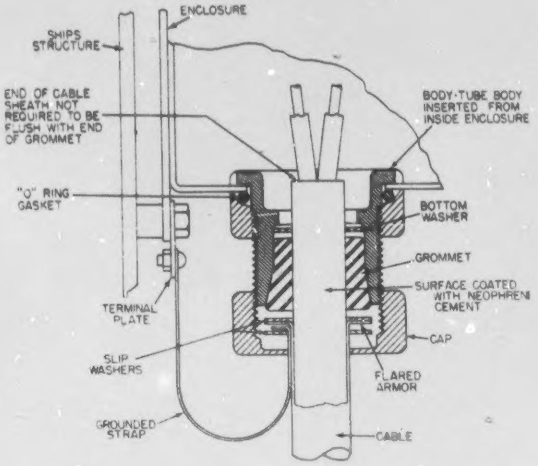

SHIP'S STRUCTURE
WRAP END OF CABLE ARMOR WITH FRICTION TAPE TO A MAX. DIAMETER WHICH WILL PASS THROUGH THE SLIP WASHERS
ENCLOSURE
LOCKNUT
BODY - TUBE BODY INSERTED FROM INSIDE ENCLOSURE
CABLE
BOTTOM WASHER
SLIP WASHERS
COAT SURFACE INDICATED WITH NEOPRENE CEMENT
A
O' RING
GROMMET
CAP
LOCKNUT
BODY
SLIP WASHERS
BOTTOM WASHER
CAP
B
ENCLOSURE
"O" RING
SEALING PLUG - SOLID

77.10
Figure 3-52.—Representative nylon stuffing tube installations.

resistant steel aluminum, depending on the requirements of the installation. For weather-deck installations, use corrosion resistant steel band with copper armored cables; zinc-coated steel with steel armor: and aluminum with aluminum armor.

When applying banding material apply one turn of banding for a single cable less than one inch in diameter. Apply two turns of banding for single cables of one inch or more in diameter and for a row of cables. Apply three turns of banding for partially loaded hangers where hanger width exceeds the width of a single cable or a single row of cable by more than one-half inch.

Cables must be supported so that the sag between supports, when practicable, will not exceed one inch. Five rows of cables may be supported from an overhead in one cable rack, and two rows of cables may be supported from a bulkhead in one cable rack. As many as 16 rows of cables may be supported in main cableways, in machinery spaces and boiler rooms. Not more than one row of cable shall be installed on a single hanger.


ENCLOSURE
SHIPS STRUCTURE
END OF CABLE SHEATH NOT REQUIRED TO BE FLUSH WITH END OF GROMMET
BODY-TUBE BODY INSERTED FROM INSIDE ENCLOSURE
"O" RING GASKET
BOTTOM WASHER
GROMMET
SURFACE COATED WITH NEOPHRENI CEMENT
TERMINAL PLATE
CAP
SLIP WASHERS
FLARED ARMOR
GROUNDED STRAP
CABLE

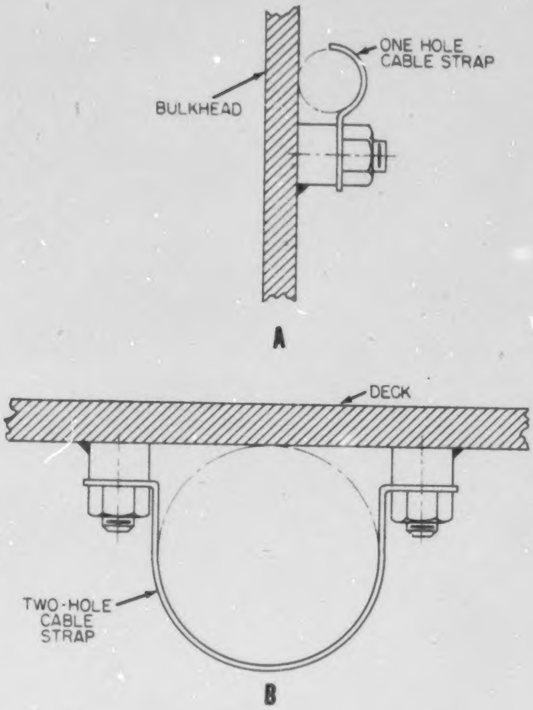
77.11
Figure 3-53.—Nylon stuffing tube grounded installation.

Modular cable supports (fig. 3-56) are being installed on a number of naval ships. The modular method saves over 50 percent in cable-pulling time and labor. Groups of cables are now passed through wide opened frames, instead of being inserted individually in stuffing tubes. The frames are then welded into the metal bulkheads and decks for cable runs.

The modular method of supporting electrical cables from one compartment to another is designed to be fireproof, water- and air-tight.

Modular insert semicircular grooved twin half-blocks are matched around each cable to form a single block. These grooved insert blocks which hold the cables (along with the spare insert solid blocks) fill up a cable support frame.

During modular armored cable installation (fig. 3-56B), a sealer is applied in the grooves of each block to seal the space between the armor and cable sheath. The sealer penetrates the braid and prevents air passage under the braid. A lubricant is used when installing the blocks which allow the blocks to slide easily over each other when packing and compressing them over the cable. Stay plates are normally inserted between every completed row to keep the blocks positioned and help distribute compression evenly throughout the frame. When a frame has been



77.15
Figure 3-54.—Single cable strap applications.

built up, a compression plate is inserted and tightened until there is sufficient room to insert the end packing.

To complete the sealing of the blocks and cables, the two bolts in the end packing are tightened evenly until there is a slight roll of the insert material around the end packing metal washers. This indicates the insert blocks and cables are sufficiently compressed to form a complete seal. The compression bolt is then backed off about 1/8 turn.

Connecting Cable

When connecting a newly installed cable to a junction box or unit of IC equipment, the length of the cable must be carefully estimated to ensure a neat installation (fig. 3-57). Sufficient cable must be stripped for proper routing and termination of the conductors. The conductors must be routed inside the enclosure with sufficient extra length allowed for re-termination at least three times (fig. 3-57B). Excessive bends or slack in the cable must be avoided in figure 3-57C). The minimum radius of bend for an electric cable is equal to approximately six times the diameter of the cable.

STRIPPING CABLE.—The cable armor may be removed by using a cable stripper of the type shown in figure 3-58. Care must be taken not to cut or puncture the cable sheath where the sheath will contact the rubber grommet of the nylon stuffing tube. If either a metal stuffing tube or cable connector is used, allow the cable (with armor) to extend at least one-eight of an inch through the tube.

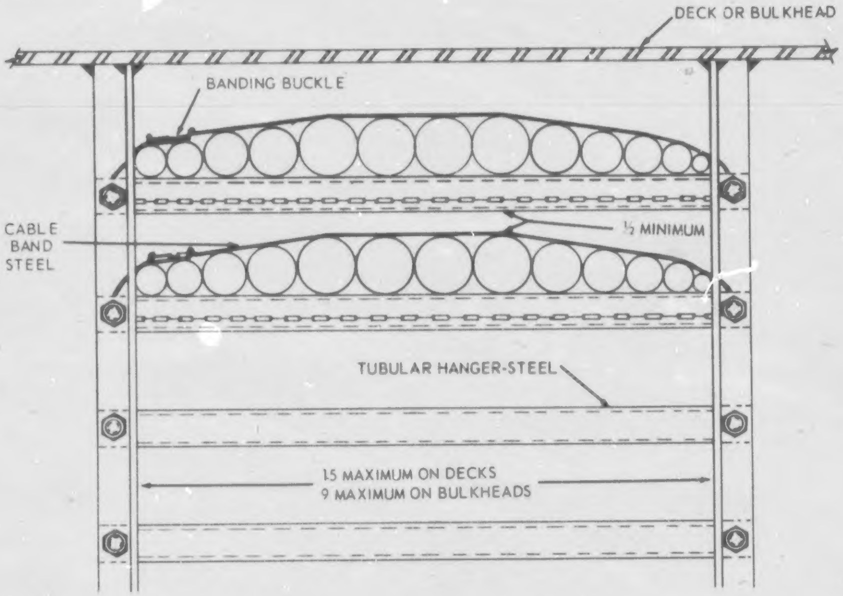
Next, remove the impervious sheath, starting a distance of at least 1 1/4 inch (or as necessary to fit the requirements of the nylon stuffing tube) from where the armor terminates. The cable stripper should be used for this job. Do not take a deep cut because the conductor insulation can be easily damaged. Flexing the cable will help separate the sheath after the cut has been made. Clean the paint from the surface of the remaining impervious sheath exposed by the removal of the armor. This paint is conducting. It is applied during manufacture of the cable and passes through the armor onto the sheath. Once the sheath has been removed, the cable filler can be trimmed with a pair of diagonal cutters.

CABLE ENDS.—When a cable is terminated in an enclosed equipment through a metal stuffing tube, the cable jacket must be tapered, and any cavities filled with plastic sealer to prevent possible water transit, in the event of flooding. The tapered section is then wrapped with synthetic resin tape, and the end of the tape served with treated glass cord.

When a cable is terminated in an enclosed equipment through a nylon stuffing tube, the cable jacket is cut square and allowed to protrude through the grommet as shown in figure 3-52A.

When a connector is used for cable termination, the armor is cut back and taped, and the square cut jacket allowed to protrude through the connector about 1/8'' as shown in figure 3-52.

The ends of cables terminating in open equipment are tapered, taped, served with cord and varnished, as shown in figure 3-59.



77.16

Figure 3-55.—Cables installed in a cable rack.

CONDUCTOR ENDS.—Wire strippers (fig. 3-60) are used to strip insulation from the conductors. Care must be taken to avoid nicking the conductor while removing the insulation. Side, or diagonal, cutters should not be used for stripping insulation from conductors.

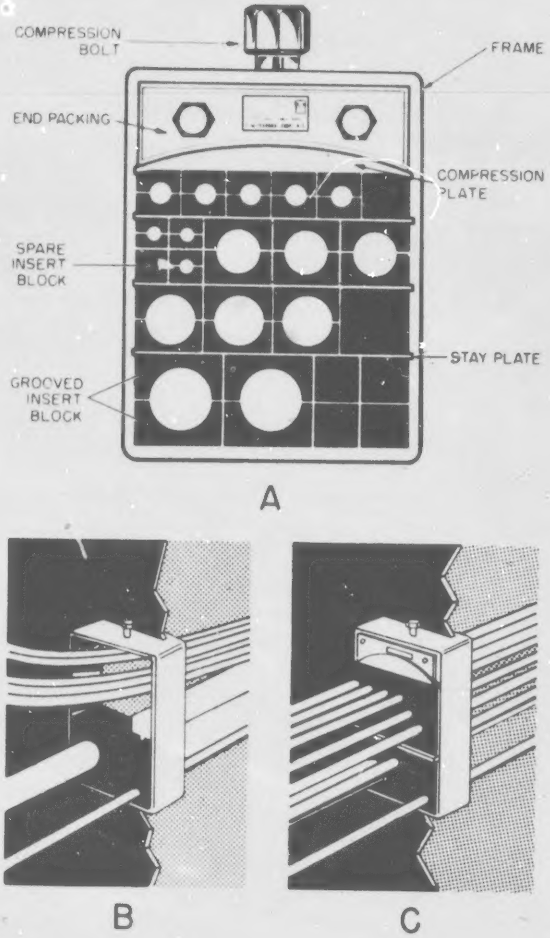
Conductor surfaces must be thoroughly cleaned before terminals are applied. After baring the conductor end for a length equal to the length of the terminal barrel, clean the individual strands thoroughly and twist them tightly together. Solder them to form a neat, solid terminal for fitting either approved clamp-type lugs or solder type terminals. If the solder type terminal is used, tin the terminal barrel and clamp it tightly over the prepared conductor (before soldering) to provide a solid mechanical joint. Conductor ends need not be soldered for use with solderless type terminals applied with a crimping tool. Do not use a side, or diagonal, cutter for crimping solderless type terminals.

Solderless type terminals may be used for all lighting, power, interior communications, and fire control applications, except with equipment provided with solder type terminals by the manufacturer, and with wiring boxes or equipment in which electrical clearances would be reduced below minimum standards by the use of the solderless type terminal.

For connection under a screwhead where a standard terminal is not practicable, an alternate method can be used. Bare the conductor for the required distance and thoroughly clean the strands. Then twist the strands tightly together, bend them around a mandrel to form a suitable size loop (or hook where the screw is not removable), and dip the prepared end into solder. Remove the end, shake off the excess solder, and allow it to cool before connecting it.

After the wiring installation has been completed, the insulation resistance of the wiring circuit must be measured with a megger or similar (0-100 megohm, 500 volt d-c) insulation resistance measuring instrument. Do not energize a newly installed, repaired, or modified wiring circuit without first ascertaining (by insulation tests) that the circuit is free of short circuits and grounds.

LACING CONDUCTORS.—Conductors within equipment must be kept in place in order to



77.296

Figure 3-56. — Modular cable supports.

present a neat appearance and facilitate tracing of the conductors when alterations or repairs are required. When conductors are properly laced, they support each other and form a neat, single cable.

The most common lacing material is waxed cord. The amount of cord required to single lace a group of conductors is approximately 2 1/2 times the length of the longest conductor in the group. Twice this amount is required if the conductors are to be double laced.

Before lacing, lay the conductors out straight and parallel to each other. Do not twist them together because twisting makes conductor lacing and tracing difficult.

A shuttle on which the cord can be wound will keep the cord from fouling during the lacing operations. A shuttle similar to the one shown in figure 3-61 may easily be fashioned from aluminum, brass, fiber, or plastic scrap. Rough edges of the material used for the shuttle should be smoothed.

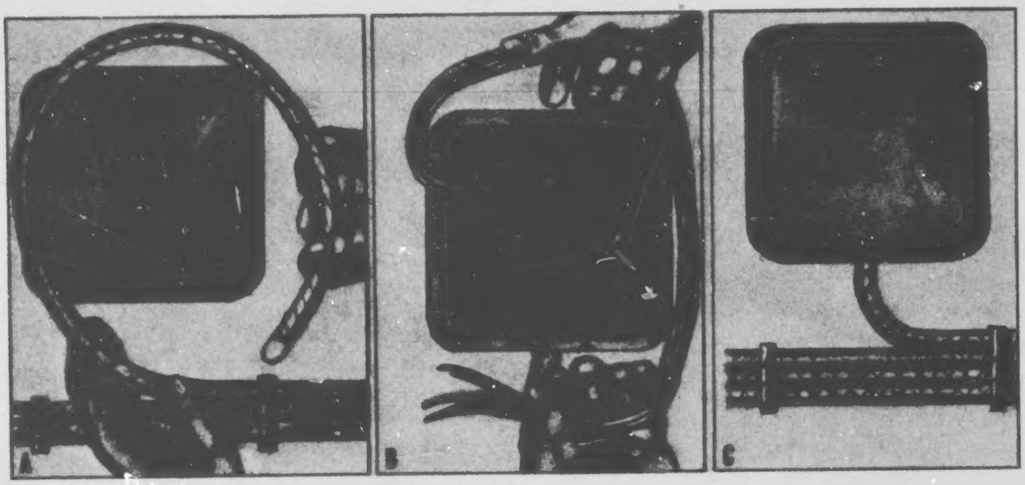
To fill the shuttle for single lace, measure the cord, cut it, and wind it on the shuttle. For double lace, proceed as before, except double the length of the cord before winding it on the shuttle, and start the ends on the shuttle in order to leave a loop for starting the lace.

Some installations, however, require the use of twisted wires. One example is the use of "twisted pairs" for the a-c filament leads of certain electron tube amplifiers to minimize radiation of their magnetic field, thus preventing annoying hum in the amplifier output. You should duplicate the original layout, when replacing such twisted leads, and when relacing and wiring harness.

Single lace may be started with a square knot and at least two marling hitches drawn tight. Details of the square knot and the marling hitch are shown in figure 3-62. Do not confuse the marling hitch with a half hitch. In the marling hitch, the end is passed over and under the strand (step 1). After forming the marling hitches, draw them tight against the square knot (step 2). The lace consists of a series of marling hitches evenly spaced at one-half inch to one-inch intervals along the length of the group of conductors, as indicated in step 3.

When dividing conductors to form two or more branches, follow the procedure illustrated in figure 3-63. Bind the conductors with at least six turns between two marling hitches, and continue the lacing along one of the branches (fig. 3-63A). Start a new lacing along the other branch. To keep the bends in place, form them in the conductors before lacing. Always add an extra marling hitch just prior to a breakout (fig. 3-63B).

Double lace is applied in a manner similar to single lace, except that it is started with the telephone hitch and is double throughout the



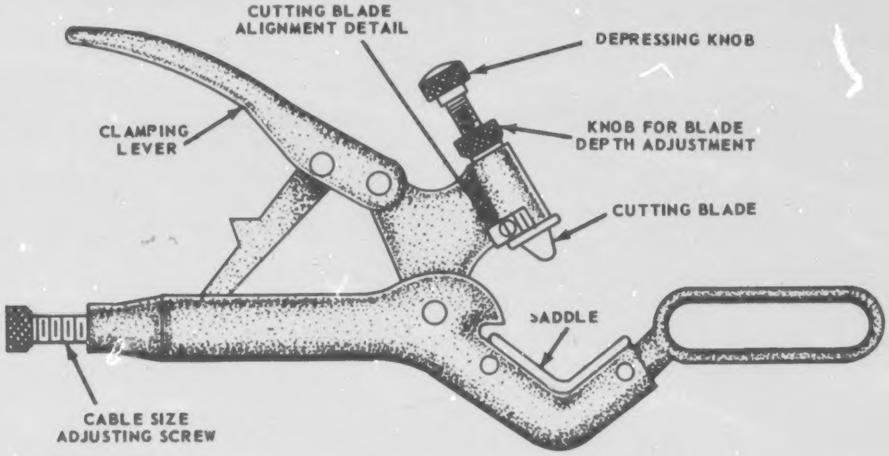
140.15(140B)

Figure 3-57.—Connecting cable to a junction box.

length of the lacing (fig. 3-64). Double, as well as single lace may be terminated by forming a loop from a separate length of cord and using it to pull the end of the lacing back underneath a serving of approximately eight turns (fig. 3-65).

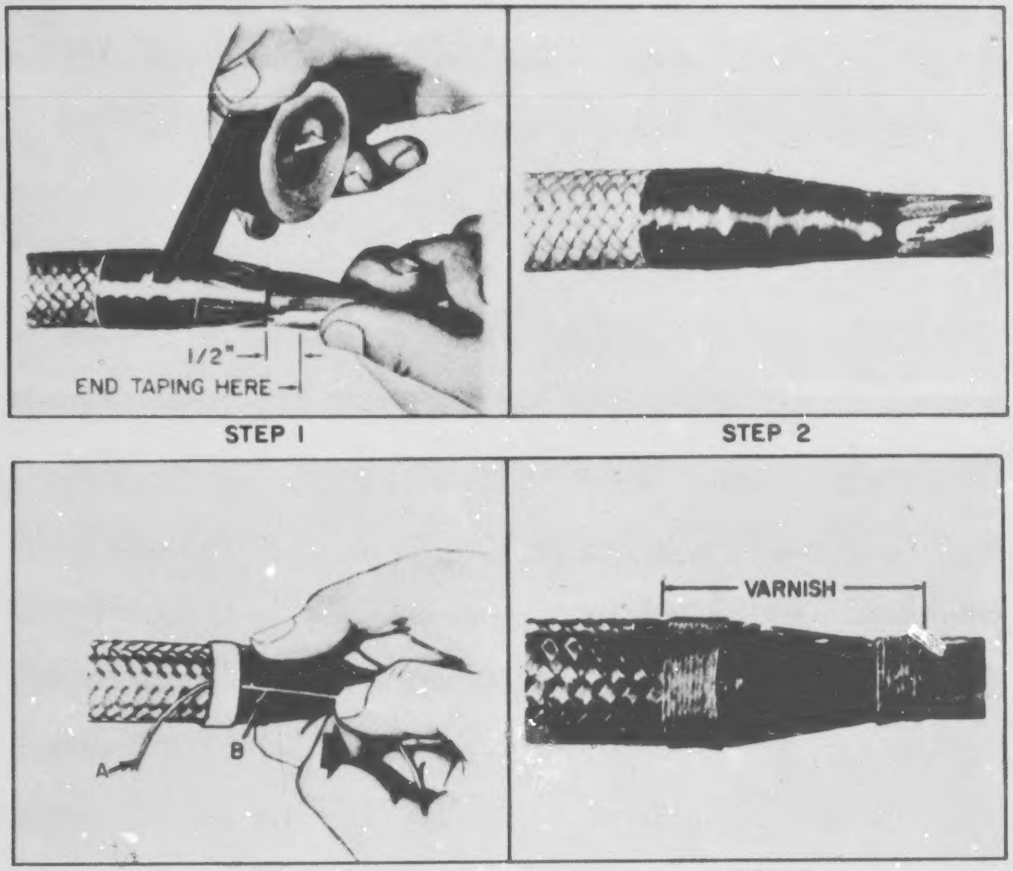
Lace the spare conductors of a multiconductor cable separately, and secure them to active conductors of the cable with a few telephone hitches. When two or more cables enter an enclosure, each cable group should be laced separately. When groups parallel each other, they should be bound together at intervals with telephone hitches (fig. 3-66).

Conductor ends (3000 cm or larger) should be served with cord to prevent fraying of the insulation (fig. 3-67).


CUTTING BLADE ALIGNMENT DETAIL
DEPRESSING KNOB
CLAMPING LEVER
KNOB FOR BLADE DEPTH ADJUSTMENT
CUTTING BLADE
SADDLE
CABLE SIZE ADJUSTING SCREW

77.22

Figure 3-58.—Cable strippers.

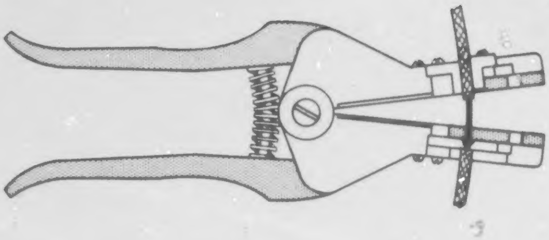

1/2"
END TAPING HERE
A
B
VARNISH

STEP 1 STEP 2

STEP 3 STEP 4

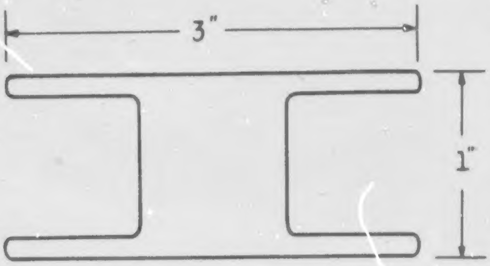
29.226(140)A

Figure 3-59. — Preparing cable ends.



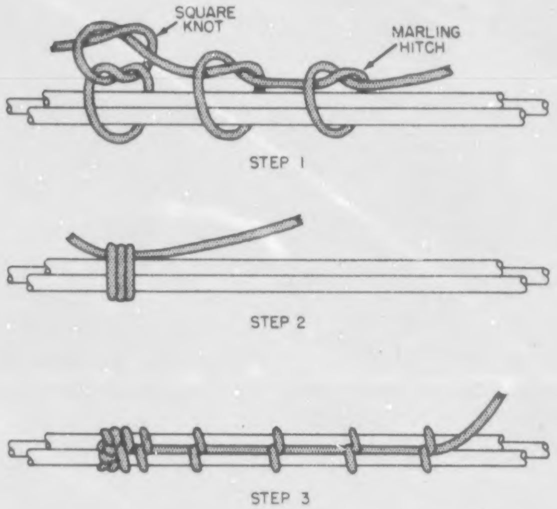
1.24

Figure 3-60. — Mechanical wire stripper.



5.138

Figure 3-61. — Lacing shuttle.



12.247(77)A
Figure 3-62.—Applying single lace.

COAXIAL CABLE

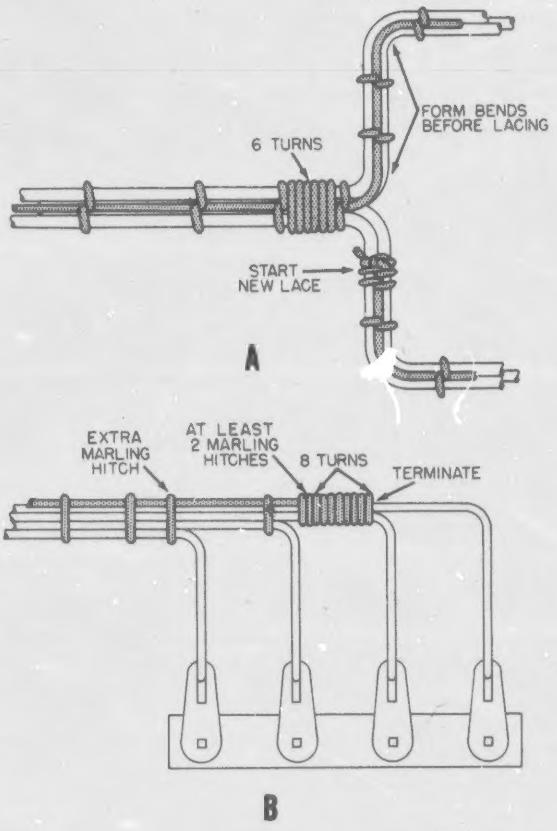
Coaxial cable is used to conduct small signal voltages and to protect these voltages from radiated radio frequencies (RF) signals. The RF signals, if induced into the conductor, would result in the distortion of the small signal voltages.

Some of the applications of coaxial and coaxial-type cables include antenna lines for ship's entertainment systems, ship's TV systems, and twinax cable that is used to connect the rodmeter of the electromagnetic underwater log to the amplifier of the indicator transmitter.

Construction of Coaxial Line

The coaxial transmission line has a center conductor that is separated from, and completely surrounded by, an outer conductor. The conductors are separated by a solid or semisolid dielectric, or by air and small insulating spacers called beads. Figure 3-68 illustrates the makeup of general purpose coaxial cable.

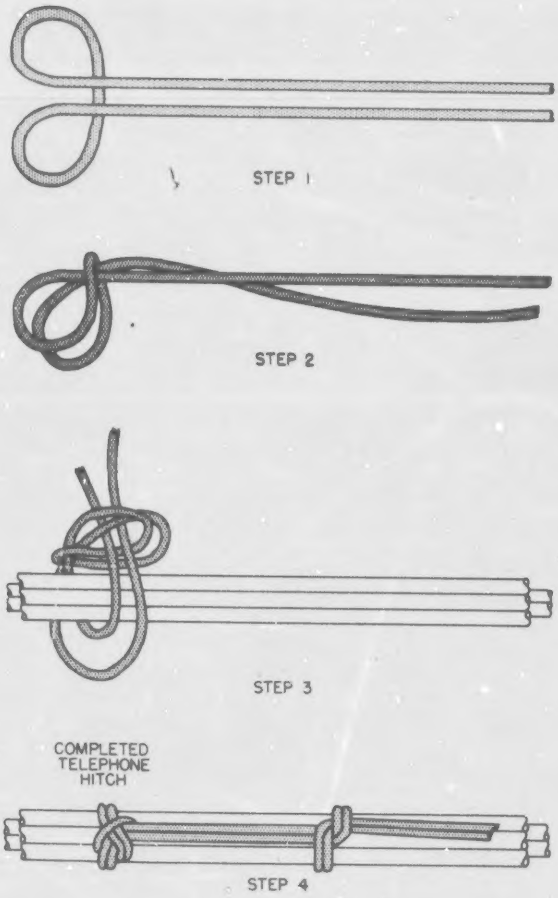
Coaxial lines are small, light in weight, and will conduct a relatively wide band of frequencies. These lines are of three types—flexible, semirigid, and rigid.



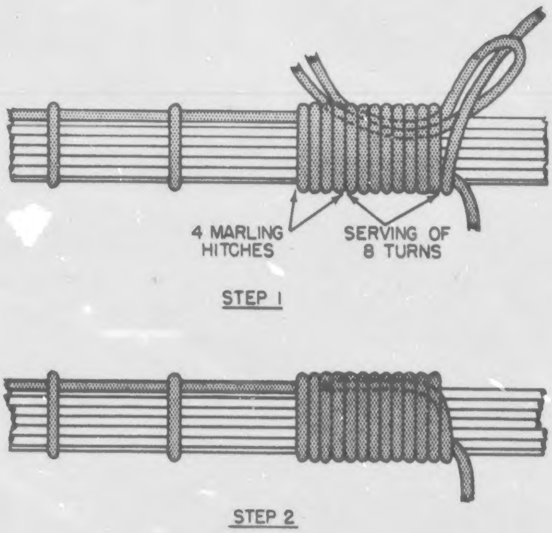
12.247(77)B
Figure 3-63.—Lacing branches and breakouts.

- Flexible coaxial cables are a simple and popular means of transmitting radio frequency energy. They are made in a wide range of sizes and electrical characteristics.

- There are many constructional variations between the flexible coaxial cables and the rigid coaxial lines which fall in the broad category of semirigid, or semiflexible lines. These lines can be fabricated and shipped in continuous lengths to 2,000 feet. The outer conductor is a smooth-drawn or corrugated tubing of ductile metal which may be covered for abrasion protection or for corrosion resistance. They have been separated into two main classes—airspaced lines and solidudielectric lines. The dielectric material of the airspaced lines may be



5.139.1
Figure 3-64. —Starting double lace with the telephone hitch.



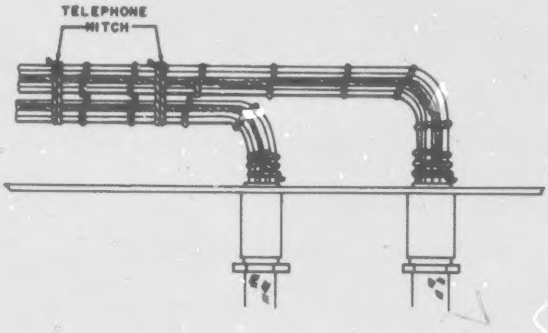
5.140.1
Figure 3-65. —The loop method of terminating the lace.

a continuous ribbon, rod, or tube which is placed between the inner and outer conductor. The solid dielectric type is fabricated with a solid or continuous insulating material between the inner and outer conductor.

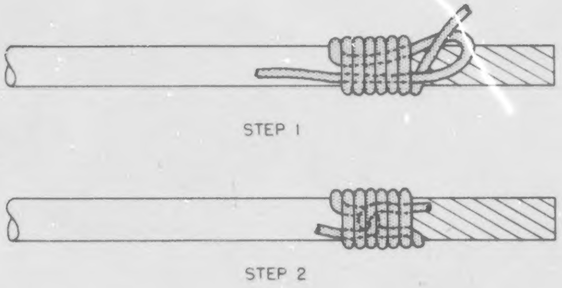
The conductors of rigid coaxial lines are different diameter tubes, one being inserted within the other. They are usually precision made tubing of high-conductivity, hard-drawn, copper, although extruded aluminum or copper-coated steel has been used. The inner conductor is rigidly supported by some type of dielectric material in the form of a bead or pin which is mechanically crimped or press fitted. Rigid coaxial lines are designated by the outside diameter of the outer conductor and are fabricated in 20-foot sections with couplings at each end.

COAXIAL CABLE CONNECTORS

Coaxial cables are connected by means of a plug or receptacle assembly (figure 3-69).



5.139
Figure 3-66. —Binding cable groups with the telephone hitch.

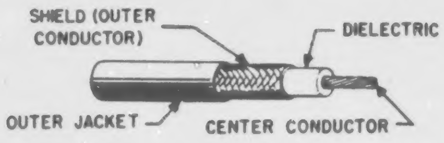

STEP 1
STEP 2

5.140.2
Figure 3-67.—Serving conductor ends.

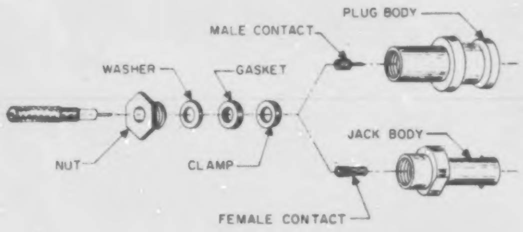
The details of attaching a connector to coaxial cable are shown in figure 3-70. The first step is sliding the nut, washer, and gasket over the cable jacket. Notice that the V-groove of the gasket faces the cable end. Then the braid is combed and bent out of the way (step 2). As shown in step 3, the braid wires are tapered toward the center conductor and the clamp slides over them and onto the jacket. In step 4, the braid wires are formed over the clamp and trimmed to proper length; next, the bushing slides over the dielectric and the contact (male or female) is soldered to the center conductor. The connector is then assembled in step 5 by tightening the nut after sliding the plug body (male or female) into position and moving the gasket into contact with the sharp edge of the clamp.

STANDARD SYSTEM OF DESIGNATING CABLE CONNECTORS

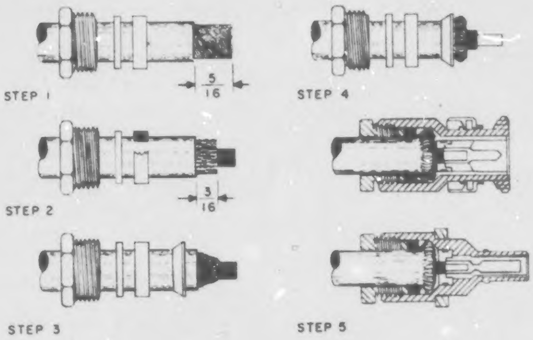
Because there is a wide variety of cable connector designs it is necessary to use a standard system of designation to identify them. Without the designation system it would be difficult to order replacement connectors. The


SHIELD (OUTER CONDUCTOR)
DIELECTRIC
OUTER JACKET
CENTER CONDUCTOR

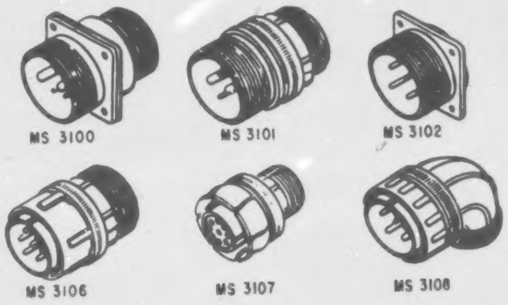
29.226(140B)
Figure 3-68.—General purpose coaxial cable.


PLUG BODY
MALE CONTACT
WASHER
GASKET
NUT
CLAMP
JACK BODY
FEMALE CONTACT

140.153
Figure 3-69.—Exploded view of a standard BNC connector.


STEP 1
5/16
STEP 4
STEP 2
3/16
STEP 3
STEP 5

140.154
Figure 3-70.—Installing a connector.


MS 3100
MS 3101
MS 3102
MS 3106
MS 3107
MS 3108

12.76
Figure 3-71.—Connector shells.

system uses an alpha-numeric code to indicate the shell type, shell design, size, and insert type, style, and position. An example is the designator MS3100-A-11PX.

- The letters MS form the prefix and identify the designation system, Military Standard.
- The number 3100 indicates the shell type and identifies it as being one of the types shown in figure 3-71.
- The letter A stands for a solid-shell connector. Other letters used, with their meanings, follow:

  B — split shell
  C — pressurized
  E — environment resistant
  K — fireproof
  R — lightweight environment

- The number 11 indicates the type of insert pin arrangement that is used in the connector.
- The letter P means that the insert is a pin (male) insert. The letter S is used to indicate a socket (female) insert.
- The letter X designates a nonstandard contact position or angle that the insert is rotated from the standard position. Other nonstandard positions are designated W, Y, or Z. No letter at the end of the designator indicates the standard contact position.

FABRICATING A CABLE ASSEMBLY

You may on occasion be required to fabricate a cable assembly. The type of connector to use is normally specified in the maintenance instructions manual for the particular installation. To provide a quality connection, follow a prescribed procedure.

The following is an outline for attaching a multipin connector to a cable:

- Disassemble the connector to allow access to the terminals.
- Cut the cable to correct length.
- Strip away insulation with a wire stripper or knife. When using a knife, avoid cutting or nicking the wire strands. Tin the bare wire ends.
- Run the wires through the connector assembly and coupling nuts.
- See that all contact surfaces are clean.
- Flow rosin-core solder into the connector terminals. Insert each wire into its terminal while holding the tip of the soldering iron against the terminal. As the solder melts, push the wire into the terminal cavity. Remove the heat source — holding the wire steady while the solder cools. (Be careful to avoid damaging the connector insulation with the soldering iron.) When soldering the connector, follow a prearranged sequence. The recommended sequence is to start from the bottom connection and work from left to right, moving up a row at a time. After soldering the connections, solder the shields (if any) to a common terminal or ferrule. Then lace the cable and reassemble the connector, moisture proofing it if necessary.

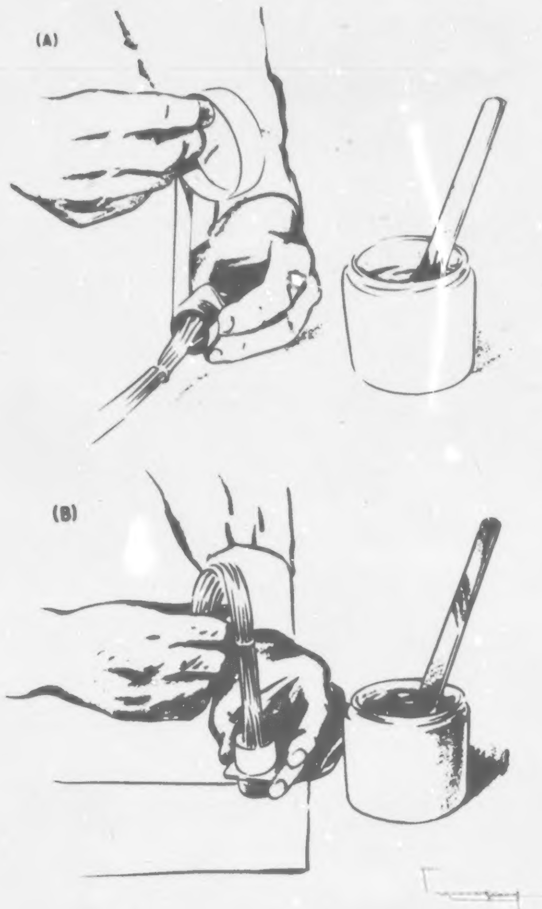
Present practice is to use type E, R, or potted connectors (moistureproof or environment-proof connectors). However, conditions sometimes demand that ordinary electrical connections on older types of cable installations be given a moistureproofing treatment. The basis of moistureproofing is the application of a sealing compound which can be obtained in kit form through the normal supply channels. The sealant should not be used on connectors located in areas where the temperatures exceed 200° F because the sealing compound deteriorates after long exposure to such temperatures.

Moistureproofing reduces failure of electrical connectors by reinforcing the wires at the connectors against the effects of vibration and lateral pressure, both of which fatigue the wires at the solder cup.

The sealing compound also protects connectors from corrosion and contamination by excluding metallic particles, moisture, and liquids. As a result of its improved dielectric characteristics, the sealing compound also reduces the possibility of arc-over between pins at the back of electric connectors.

A summary of the procedures involved in sealing (or potting as it is called) a connector follows:

- Prepare the connector by removing existing sealants and cleaning. The cleaning solvent must clean thoroughly, evaporate quickly, and leave no residue. Remove all sleeving from wires. Re-solder loose or poorly soldered connections and add a length of wire approximately 9 inches long to each unused pin. The unused pins serve to provide emergency connections. More on this later.) Remove any excess rosin



140.155
Figure 3-72.—(A) Making mold from masking tape; (B) finished potted plug.

from around the pins and the insert with a stiff bristle brush. Now, repeat the cleaning process. Then separate the wires so the sealing compound will flow evenly into all spaces.

- Prepare the potting compound. Because the ratio of the amount of accelerator to base compound is critical, the entire quantity of accelerator furnished must be added to the base compound.
- Place the plugs or receptacles on a table, arranging them so that gravity will draw the sealer to the bottom of the plug. Box receptacles or plugs without back shells must be fitted with a mold formed from masking or cellophane tape or equivalent. This mold will retain the sealant during the curing process. If the back shell is used, apply a slight amount of oil to the surface facing the potting compound to prevent the compound from adhering to it. (See fig. 3-72A and B.)
- Apply the compound with a spatula, putty knife, or paddle. Pack it around the base of the pins. Fill the part being potted completely or at least to a point that will cover a minimum of 3/8-inch of insulated wire.
- Allow the compound to cure.

If it is desired that the entire connector assembly (plug and receptacle) be sealed against fluid entering or collecting between the two parts, fit a rubber O-ring over the barrel of the plug. This O-ring will provide a seal when the two parts are engaged and will prevent moist air from entering due to variations in temperature, altitude, or barometric pressure on the ground. Rubber packing O-rings are available for this purpose through normal supply channels. Due to the aging of these rings in service, examine them each time connectors are disassembled. If deteriorated, replace them.

As mentioned earlier, a short length of wire is soldered to each spare pin. This wire will enable additional circuits to be included in the connector and can avoid the need to repair a single wire which may have failed within potted connectors. Instead of having to disassemble the connector it is now possible to have ready access to a spare pin by making a splice to one of the spare wires.

If a spare wire is not available in the connector and a single wire must be replaced, the back shell may be removed. Removal may require considerable force depending on how well the sealant adheres. Access to the desired lead may now be obtained by cutting away a part of the potting compound with a knife. If a center wire of a larger connector is defective, and is beyond easy reach from the side, it may be better to remove the sealant from the center with long nose pliers until enough is exposed to allow the defective lead to be repaired. Obviously a small soldering gun is required when working in such confined places. Complete removal of the compound may also be necessary. Regardless of the method used to gain access to the defective terminal, the plug is returned to its original condition by applying sealant to the connector in the manner previously described. The new compound will seal or vulcanize satisfactorily to any old compound remaining in the connector.

CHAPTER 4

POWER DISTRIBUTION SYSTEMS

The majority of interior communications systems on naval vessels receive their power from the interior communications switchboard; only a few of the systems are powered from local lighting and power sources. The main interior communications (IC) switchboard — on smaller ships, the only IC board — is located in the forward IC and plotting room. There may be an after board located in the No. 2 IC room, and smaller local service boards in each engineroom and in the steering gear room.

The physical construction of IC switchboards varies greatly. The switchboards installed on older ships are completely open, also live-front; the most recent types are dead-front, front-service.

This chapter describes the various types of IC switchboards, emphasizing the types installed on a modern DDG. Also included are topics on distribution systems for ship's service, emergency, and casualty power.

INTERIOR COMMUNICATIONS SYSTEMS CLASSIFICATION

IC systems are classified according to importance and readiness. The importance, classification (vital, semivital, or nonvital) defines the extent to which a system affects the maneuverability or fighting capability of the ship.

- Vital IC systems — those which, if disabled, would seriously affect the fighting effectiveness and maneuverability of the ship.
- Semivital IC systems — those which, if disabled, would impair the effectiveness to a lesser extent than the loss of a vital system.
- Nonvital IC systems — those which, if disabled, would not impair the fighting effectiveness or the maneuverability of the ship.

The readiness classification (1, 2, 3, or 4) defines the extent to which a system contributes to the operational readiness of the ship. (See table 4-1.

TYPES OF INTERIOR COMMUNICATIONS SWITCHBOARDS

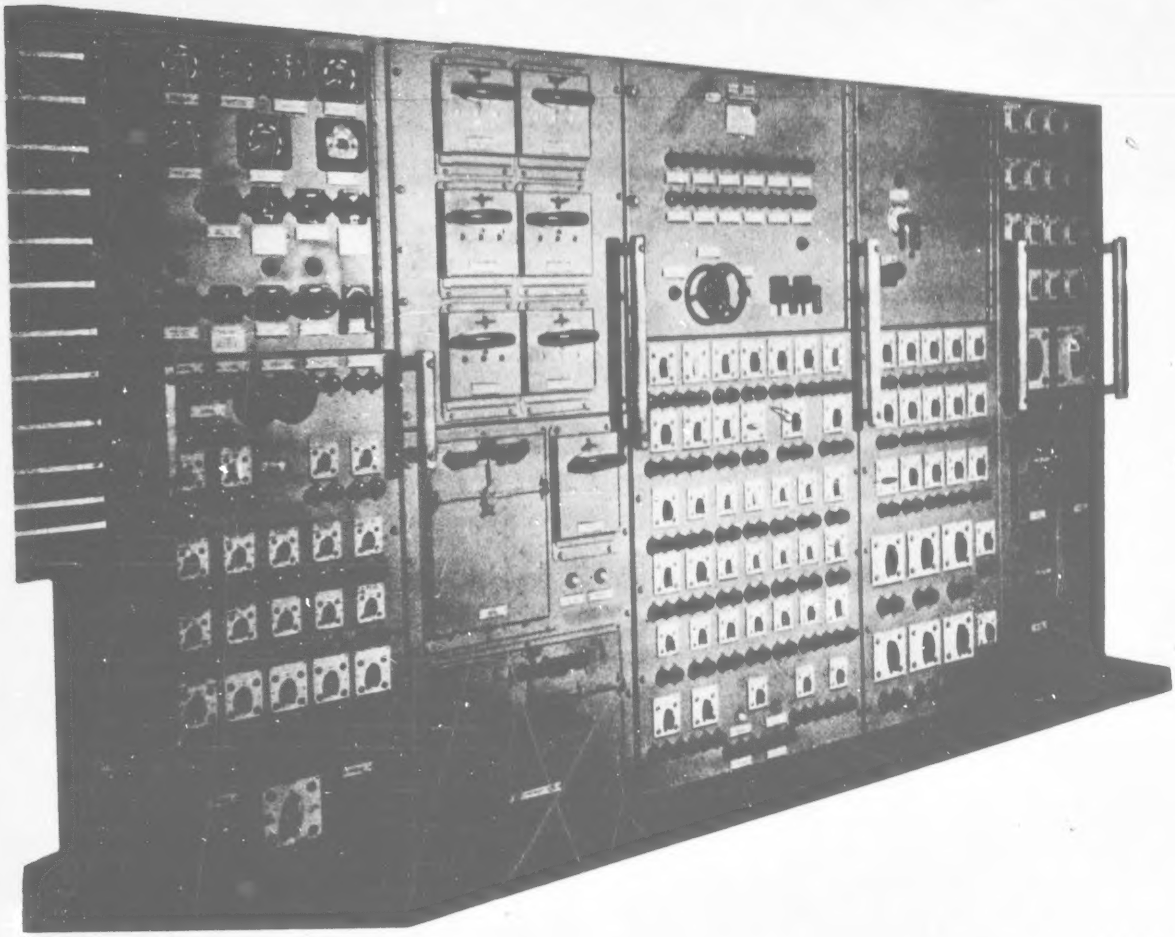
DEAD-FRONT SWITCHBOARDS

The dead-front IC switchboard (fig. 4-1) has dead-front types switches throughout. The fuses, except those mounted on the type K switches, are mounted in plug-in type combination fuseholder-blown fuse indicators. This type of switchboard has many design features

Table 4-1. — Circuit Classification by Readiness

Circuit readiness	Switch recognition color	Readiness requirement
1	Yellow	Essential to ship's safety; energized at all times.
2	Black	Essential to ship's control; energized when ship is preparing to get underway, is standing by, is underway, or is anchoring.
3	Red	Essential to complete interior control; energized during battle condition watches.
4	White	Convenience circuits; energized when required.

140.115



27.270

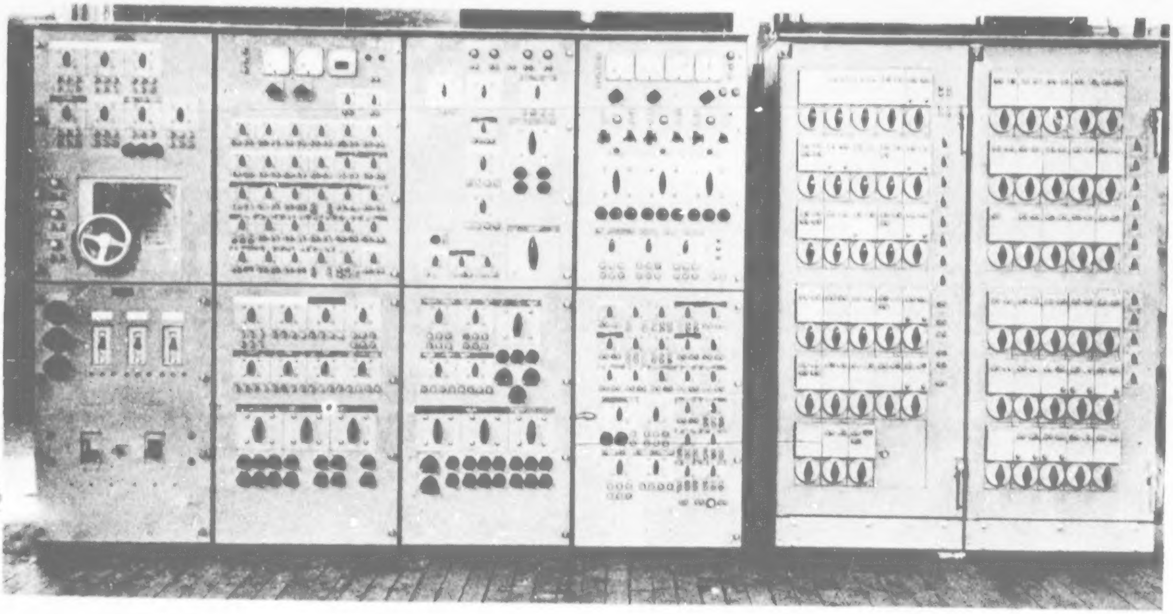
Figure 4-1.—Dead-front IC switchboard.

that serve to make it safe in operation. All connections are made behind the panel with only the switch handles accessible to the operator; fuse holders of the plug-in type are mounted perpendicular to the panel resulting, in a more compact board; and all meters, circuit breakers, and bus tie switches are mounted behind hinged panels.

DEAD-FRONT, FRONT-SERVICE SWITCHBOARD

The most recent advance in switchboards and the unit being installed aboard naval vessels today is the dead-front, front-service board. It is similar in construction to the dead-front board, yet has the additional feature of allowing all service requirements to be performed from in front of the unit. Figure 4-2 is a typical example of an installation as is currently in use. The front-service board uses a boxlike constructon with the front panels hinged for access. Switches and fuseholders up to 60 amperes, as well as all other lightweight items, are mounted on the hinged door, while the heavier hardware is mounted on the unit itself.

Terminal boards are provided within the switchboard enclosure for termination of all



140.65

Figure 4-2. —Main IC switchboard.

ship's cables, which run directly to their associated switches and fuse holders. All wiring between the terminal boards and the equipment mounted on the hinged and stationary panels is installed by the manufacturer prior to installation to ensure the free swinging of the panels without interference from, or damage to, the wiring.

In order to reduce the rigidity of the switchboard, and to permit separate movement of panels during shock, cables instead of horizontal buses are used for connection between or among board sections. Some vertical buses may be used, however, to supply sections of individual panels.

The main advantage of this type of switchboard is that it can be mounted flush against a bulkhead, no access being required in the rear of the board. This feature results in a saving of space which is a most important consideration on board ship.

SWITCHBOARD SECTIONS

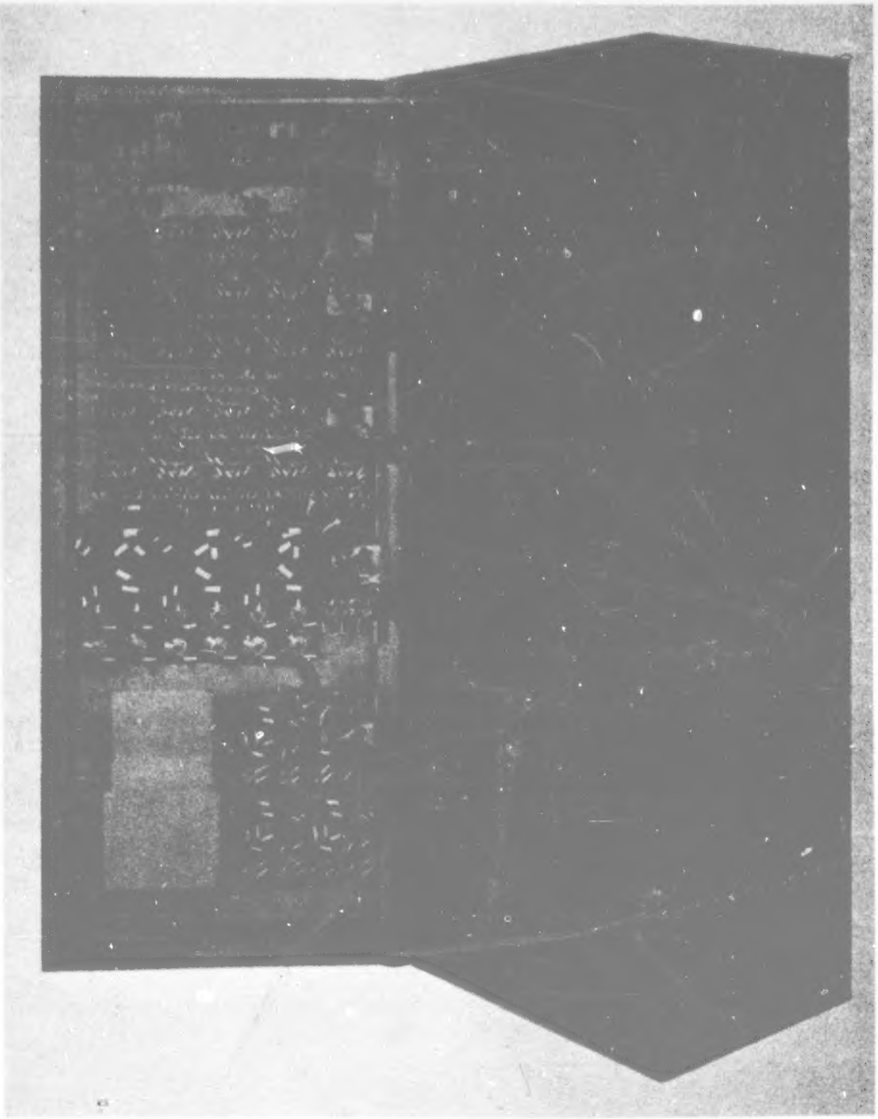
The main IC switchboard is broken down into two major subdivisions. In figure 4-2 the power distribution section comprises sections 1 thru 4, while the action-cutout section is panels 5 and 6. These sections are then further subdivided into various buses, dependent upon the specific needs of the vessel in which installed.

DISTRIBUTION SECTION

The distribution section (fig. 4-3) is typical of all main distribution units. The various IC circuits receive power from its seven buses: 450-volt, 400-Hz; 120-volt, 400-Hz, regulated and unregulated; 450/120-volt, 60-Hz; 120-volt, d-c; and 50-volt, d-c.

60-Hz Power

The 450-volt, 3-phase, 60-hertz bus is energized from one of three power sources through the use of two mechanically interlocked switches and an automatic bus transfer (ABT) switch (fig. 4-4), which selects its feed from normal, alternate, or emergency supplies. The normal supply to the main IC board is from the ship's forward switchgear group number 1S. The alternate supply to the board is from the after switchgear group number 2S while the emergency

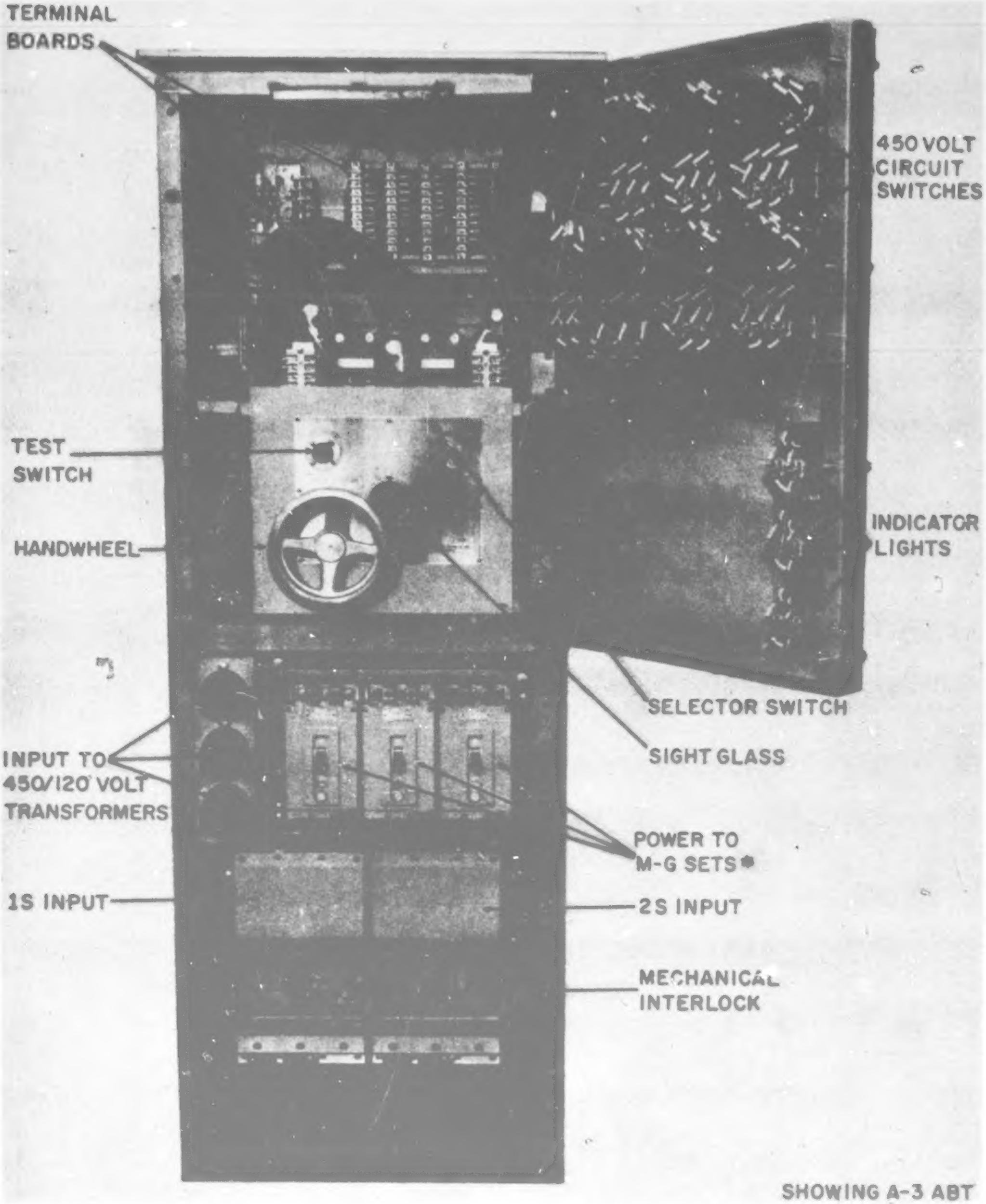


140.117

Figure 4-3.—Interior view main IC switchboard distribution section.

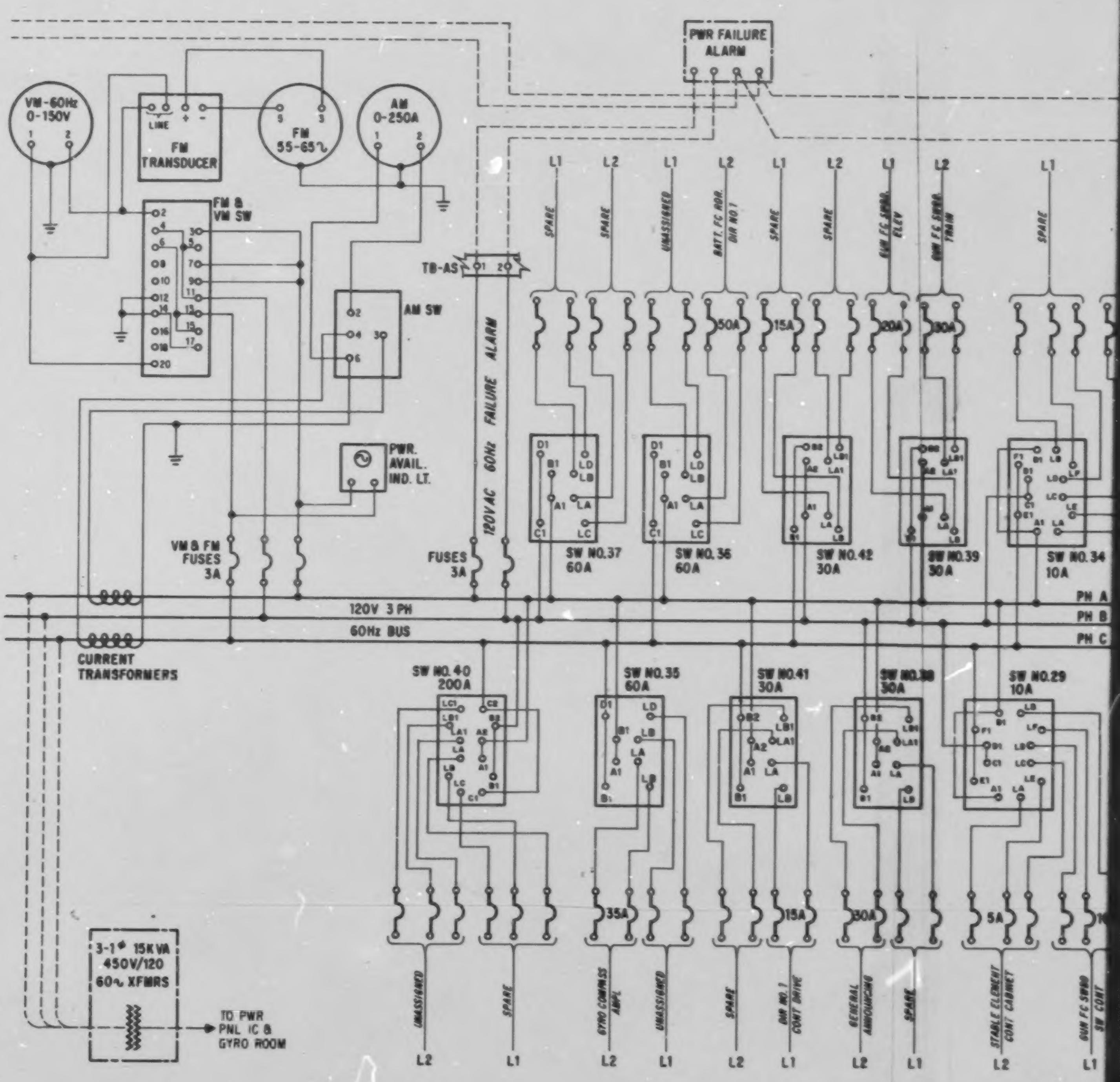
supply emanates from the nearest ship's emergency group, in this case the forward emergency switchgear 1E. Normal or alternate power is selected by two interlocked switches and becomes "Preferred" power. The bus may also be powered by a casualty power terminal installed on the board, which in turn receives its power via portable cable from a remotely located riser nearby.

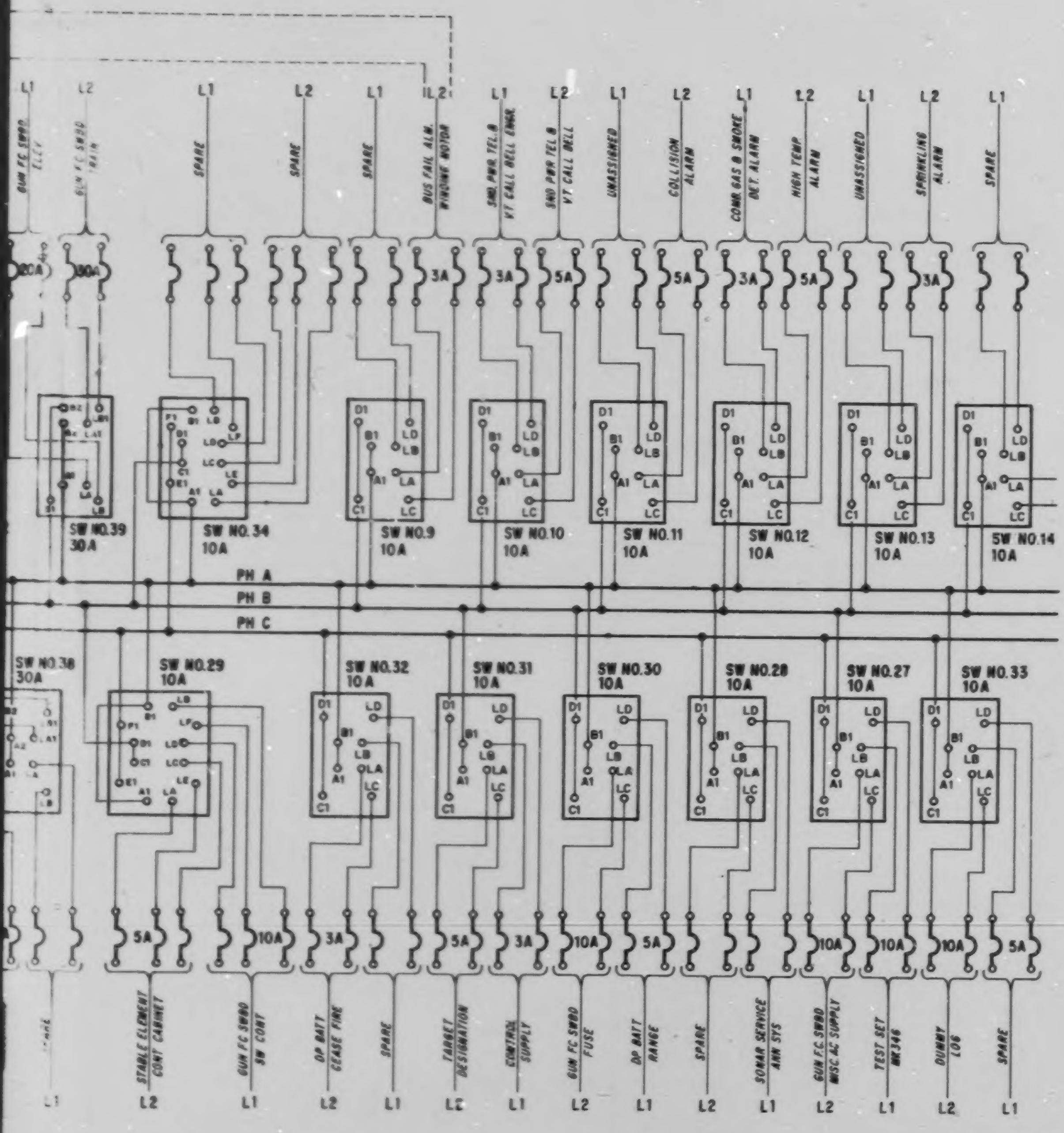
Power available indication is provided through the use of indicator lights connected via transformers to each power source. The automatic transfer device, indicator lights, and


TERMINAL BOARDS
450 VOLT CIRCUIT SWITCHES
TEST SWITCH
HANDWHEEL
INDICATOR LIGHTS
SELECTOR SWITCH
SIGHT GLASS
INPUT TO 450/120 VOLT TRANSFORMERS
POWER TO M-G SETS
1S INPUT
2S INPUT
MECHANICAL INTERLOCK
SHOWING A-3 ABT

140.67

Figure 4-4. — Type A-3 ABT and panel #1.


PWR FAILURE ALARM
VM-60Hz 0-150V
FM TRANSDUCER
LINE
FM 55-65∿
AM 0-250A
FM & VM SW
AM SW
PWR. AVAIL. IND. LT.
TB-AS
120VAC 60Hz FAILURE ALARM
VM & FM FUSES 3A
FUSES 3A
120V 3 PH
60Hz BUS
PH A
PH B
PH C
CURRENT TRANSFORMERS
SPARE
UNASSIGNED
BATT. FC HOR. DIR NO 1
GUN FC SWBD ELEV
GUN FC SWBD TRAIN
50A
15A
20A
30A
SW NO.37 60A
SW NO.36 60A
SW NO.42 30A
SW NO.39 30A
SW NO.34 10A
SW NO.40 200A
SW NO.35 60A
SW NO.41 30A
SW NO.38 30A
SW NO.29 10A
35A
5A
GYRO COMPASS AMPL
DIR NO.1 CONT DRIVE
GENERAL ANNOUNCING
STABLE ELEMENT CONT CABINET
GUN FC SWBD SW CONT
L1
L2
3-1φ 15KVA 450V/120 60∿ XFMRS
TO PWR PNL IC & GYRO ROOM


L1
L2
GUN FC SWBD ELEV
GUN FC SWBD TRAIN
SPARE
SPARE
SPARE
BUS FAIL ALM. WINDING MOTOR
SND PWR TEL & VT CALL BELL ENGR
SND PWR TEL & VT CALL BELL
UNASSIGNED
COLLISION ALARM
COMB GAS & SMOKE DET. ALARM
HIGH TEMP. ALARM
UNASSIGNED
SPRINKLING ALARM
SPARE
20A
30A
3A
5A
10A
SW NO.39 30A
SW NO.34 10A
SW NO.9 10A
SW NO.10 10A
SW NO.11 10A
SW NO.12 10A
SW NO.13 10A
SW NO.14 10A
PH A
PH B
PH C
SW NO.38 30A
SW NO.29 10A
SW NO.32 10A
SW NO.31 10A
SW NO.30 10A
SW NO.28 10A
SW NO.27 10A
SW NO.33 10A
D1
B1
A1
C1
E1
F1
LA
LB
LC
LD
LE
LF
STABLE ELEMENT CONT CABINET
GUN FC SWBD SW CONT
DP BATT CEASE FIRE
SPARE
TARGET DESIGNATION
CONTROL SUPPLY
GUN FC SWBD FUSE
DP BATT RANGE
SPARE
SONAR SERVICE ANN SYS
GUN F.C. SWBD MISC AC SUPPLY
TEST SET MK346
DUMMY LOG
SPARE

140.118

Figure 4-5.—IC switchboard wiring diagram.

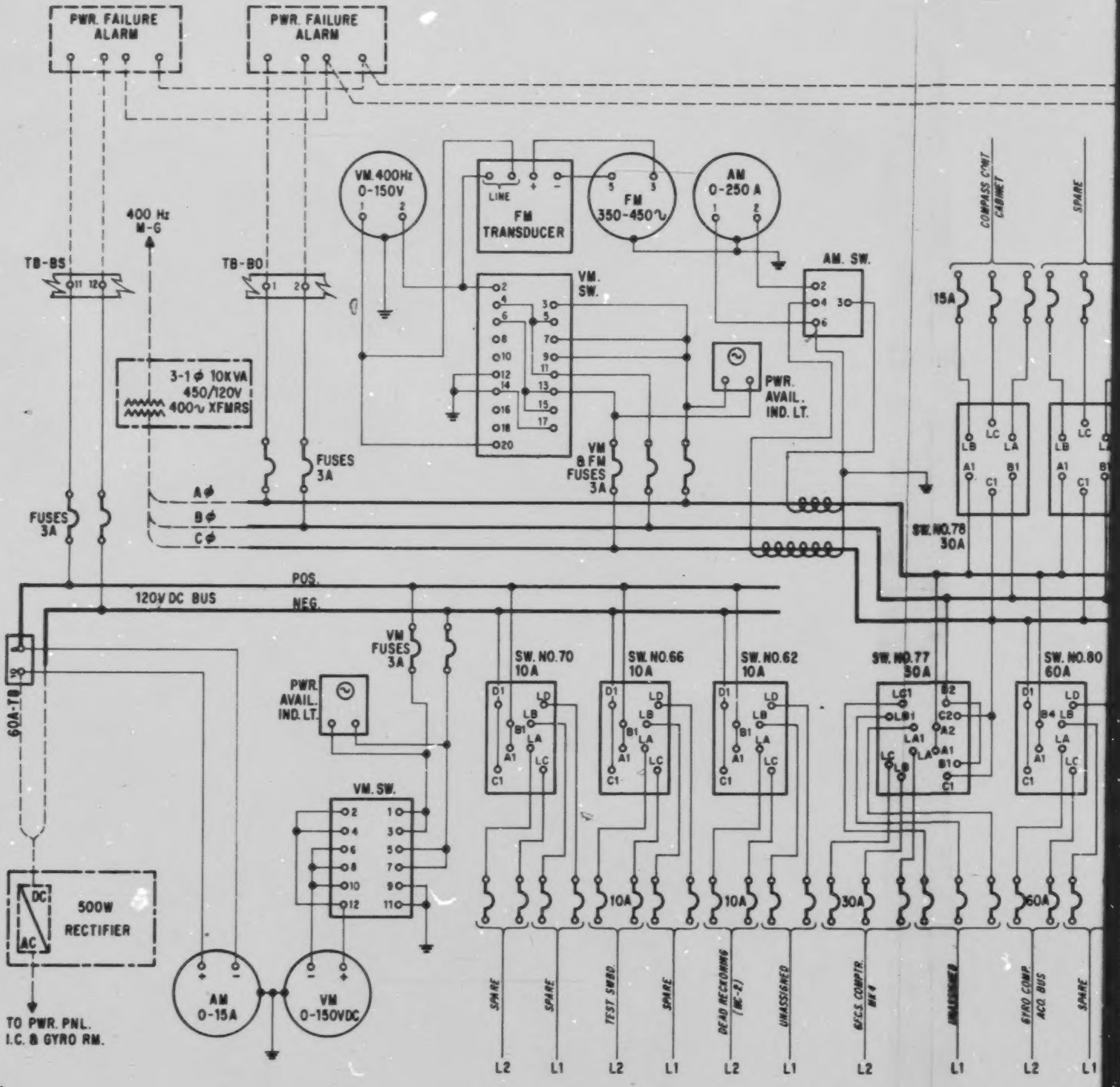
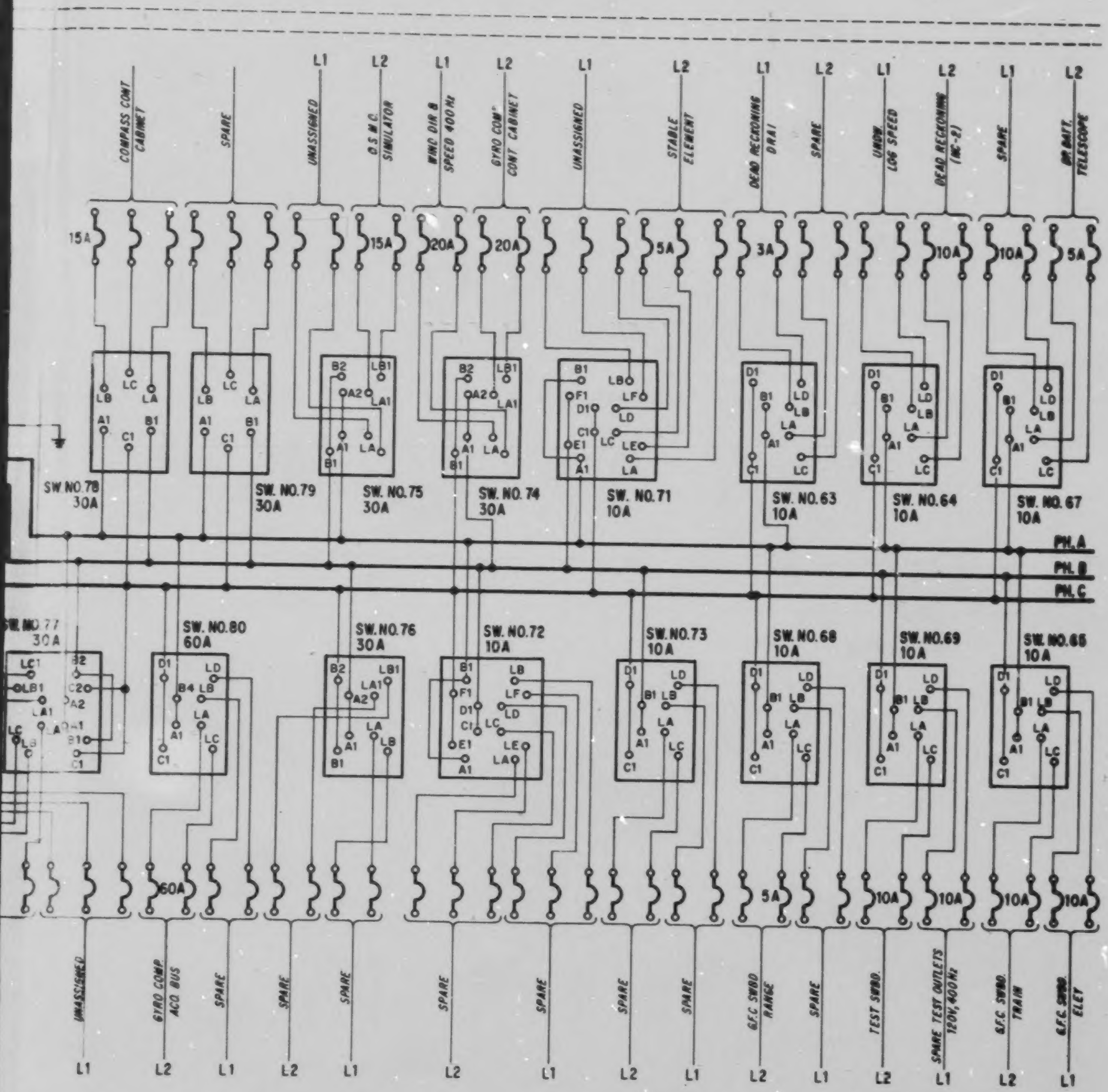

PWR. FAILURE ALARM
PWR. FAILURE ALARM
400 Hz M-G
TB-BS
11 12
TB-BO
1 2
3-1 ϕ 10KVA 450/120V 400∿ XFMRS
FUSES 3A
FUSES 3A
VM 400Hz 0-150V
LINE
FM TRANSDUCER
FM 350-450∿
AM 0-250 A
AM. SW.
VM. SW.
PWR. AVAIL. IND. LT.
VM & FM FUSES 3A
Aϕ
Bϕ
Cϕ
POS.
NEG.
120V DC BUS
60A-TB
VM FUSES 3A
PWR. AVAIL. IND. LT.
VM. SW.
500W RECTIFIER
DC
AC
TO PWR. PNL. I.C. & GYRO RM.
AM 0-15A
VM 0-150VDC
SW. NO. 70 10A
SW. NO. 66 10A
SW. NO. 62 10A
SW. NO. 77 30A
SW. NO. 80 60A
SW. NO. 78 30A
15A
COMPASS CONT CABINET
SPARE
10A
10A
30A
60A
SPARE
SPARE
TEST SWBD.
SPARE
DEAD RECKONING (MK-2)
UNASSIGNED
GFCS COMPTR. MK 4
UNASSIGNED
GYRO COMP. ACQ. BUS
SPARE
L2
L1
L2
L1
L2
L1
L2
L1
L2
L1

Figure 4-6.--IC


COMPASS CONT CABINET
SPARE
L1 UNASSIGNED
L2 O.S.M.C. SIMULATOR
L1 WIND DIR & SPEED 400 Hz
L2 GYRO COMP CONT CABINET
L1 UNASSIGNED
L2 STABLE ELEMENT
L1 DEAD RECKONING DRAI
L2 SPARE
L1 UNDW. LOG SPEED
L2 DEAD RECKONING (NC-2)
L1 SPARE
L2 DR. BATT. TELESCOPE
15A
15A
20A
20A
5A
3A
10A
10A
5A
SW. NO. 78 30A
SW. NO. 79 30A
SW. NO. 75 30A
SW. NO. 74 30A
SW. NO. 71 10A
SW. NO. 63 10A
SW. NO. 64 10A
SW. NO. 67 10A
PH. A
PH. B
PH. C
SW. NO. 77 30A
SW. NO. 80 60A
SW. NO. 76 30A
SW. NO. 72 10A
SW. NO. 73 10A
SW. NO. 68 10A
SW. NO. 69 10A
SW. NO. 66 10A
60A
5A
10A
10A
10A
10A
UNASSIGNED L1
GYRO COMP. ACO BUS L2
SPARE L1
SPARE L2
SPARE L1
SPARE L2
SPARE L1
SPARE L2
SPARE L1
G.F.C. SWBD RANGE L2
SPARE L1
TEST SWBD. L2
SPARE TEST OUTLETS 120V, 400Hz L1
G.F.C. SWBD. TRAIN L2
G.F.C. SWBD. ELEV L1

140.119

Figure 4-6. —IC switchboard wiring diagram.

all appropriate switching and instrumentation are located in panel #1.

The 120-volt, 3-phase, 60-hertz bus receives its power from panel #1 via a bank of three 450/120-volt, 60-hertz, 15-kva transformers, remotely located, in panel #2. Refer to figure 4-5. As can be seen in figure figure 4-2, meters for voltage and current indication are located on this panel. It is from this bus that these meters receive their power. (There is also a megohmmeter installed on this panel, however this unit will be discussed later.) This panel disseminates both single- and 3-phase, 120-volt a-c power as required.

400-Hz Power

A 450-volt, 400-hertz, 3-phase, regulated bus is located in panel #4 of the board. This bus is powered by any of three 30-KW motor generator sets located near the IC room and controlled from panel #4. The power to these M-G sets is from the 450-volt, 3-phase supply of panel #1. Indicator lights are located on panel #4 for power available indication from each of the M-G sets. See figure 4-6.

Installed also in panel #4 is a 450-volt, 400-hertz, 3-phase unregulated bus. This bus is intended to receive its power from the ship's 400-hertz supply, although on most installations it is at present connected to the regulated source.

To facilitate weapons requirements, a 450-volt, 400-hertz, 3-phase weapons direction equipment bus has been installed. Through a triple-throw rotary snap switch this bus may receive its power from either of three sources: (1) Weapons Director Equipment Motor Generator (#3), (2) 450-volt, 400-hertz regulated bus, or (3) 450-volt, 400-hertz unregulated bus.

Via a bank of three remotely located transformers, panel #4 also supplies a 120-volt, 400-hertz, 3-phase regulated bus. The primary voltage supply for these transformers is the higher voltage regulated supply.

Additionally, a 120-volt, 400-hertz, 3-phase unregulated bus is installed. At present it is, on most installations, connected to the regulated bus; however, it was originally intended to be connected to the unregulated, higher voltage via a separate transformer bank.

D-C Power Buses

Direct current in the magnitude of 120 volts is supplied to panel #3 of the switchboard from remotely located rectifier supplies. These units receive their excitation from the 450-volt supply of panel #1 (fig. 4-6). The unit in operation is selected by a double-pole, double-throw rotary snap switch located on panel #3. Indicator lights tell the toperator which of the two units is in operation.

A 50-volt d-c supply for the weapons control units is also provided to panel #3 via a separate set of remotely located rectifiers. The excitation is again the 450-volt supply of panel #1. Again, indicator lights are provided.

Instrumentation

Located on panel #2 are an ammeter and a voltmeter. The former indicates 120-volt, 60-hertz current of phases A and C. Current transformers and switching are provided. Phase B current herein is the vectorial sum of the other two currents.

The voltmeter can by the use of a selector switch be used to indicate phases A and B, B and C, or A and C.

To indicate the 450-volt, 400-hertz, 3-phase regulated supply of panel #4, a voltmeter is installed to indicate phases B and C, and C and A of the bus, as well as each bus phase to ground. Additionally, this instrument through its selector switch indicates phases A to B of each generator. A 450/115-volt transformer is employed in conjunction with this voltmeter.

Frequency indication is provided, by meter, in parallel with the voltmeter.

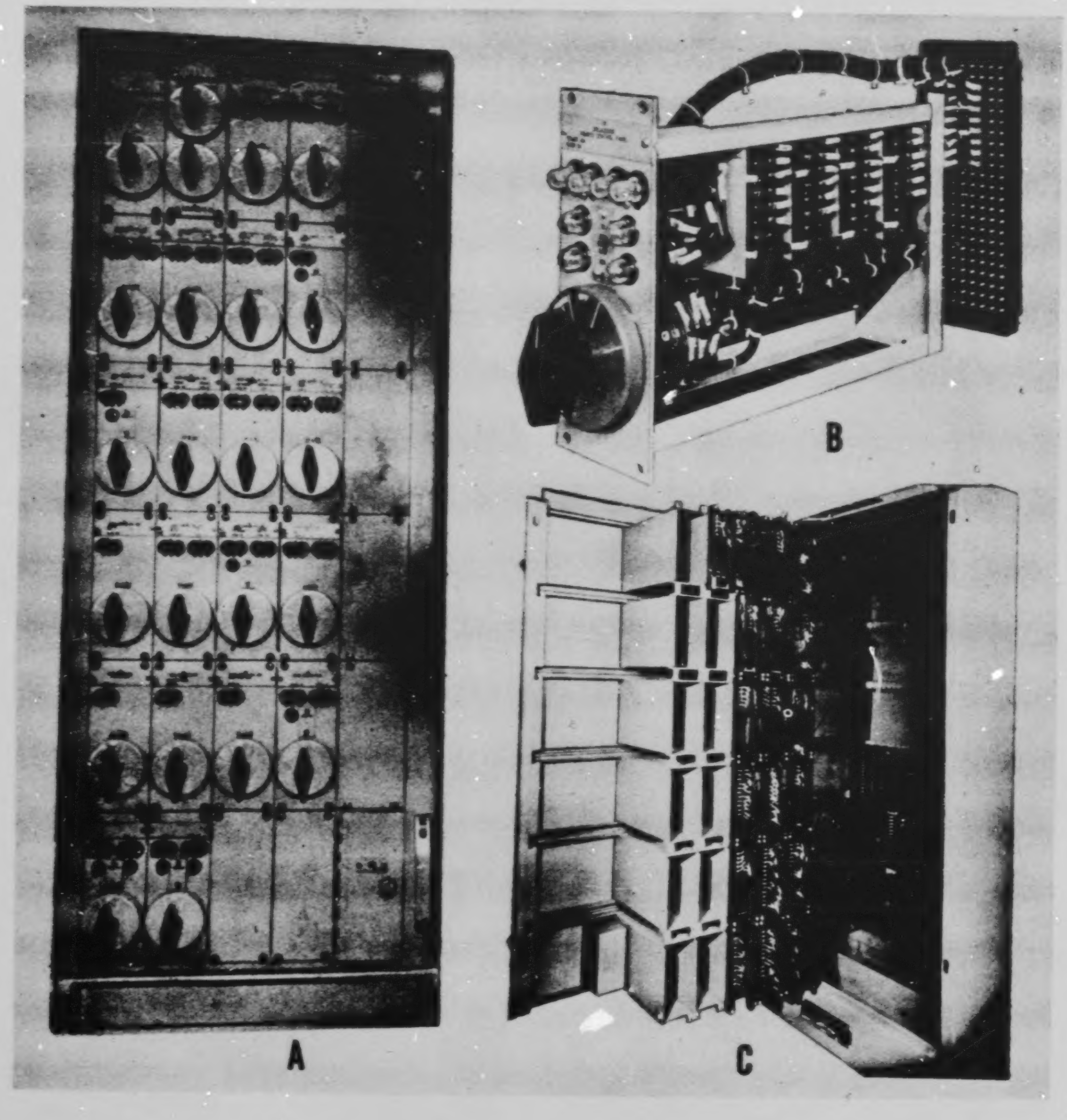
Current indication on the 450-volt, 400-hertz, regulated supply is provided by a meter which can, by the positioning of its selector switch, indicate each bus phase as well as phase A of each of the generators.

In order to permit parallel operation of the generators, a synchroscope and synchronizing lights and the necessary switching are provided on panel #4.

Additional Switchboard Equipment

A megohmmeter is installed in panel #2 to assist in circuit testing. The power supply for this unit is installed in the switchboard, and the unit is energized through a single-throw rotary-snap switch installed on the panel.

Remote from the switchboard but nonetheless a part of the unit are the Bus Failure Alarms. These units are used to indicate the lose of 120-volt, 60-hertz; 120-volt, d-c; 450-volt, 400-hertz, unregulated; 120-volt, 400-hertz, regulated; and 120-volt, 400-hertz, unregulated power supplies.



55.316
Figure 4-7.—Dead-front, front service section. (A) Front view; (B) Action cutout unit; (C) Rear view, door open.

ACTION CUTOUT (ACO) SECTION

In order to facilitate the removal of damaged portions of certain IC cercuits from the main indicating bus, and to permit the use of alternate information suppliers to specific indication or control units, the ACO section (fig. 4-7) of the IC switchboard is installed alongside the power section. Through the use of JR type switches (chapter 3) and synchro overload transformers (explained later in this chapter) in drawout units, it is possible to divide the various included circuits into their component legs.

In the typical installation, panel #5 of the switchboard is used to switch in and out the repeater and control circuits of the gyro compass system (LC). Through the proper manipulation of switches, either the main or the auxiliary compass may be selected as the information-sending device to the many repeaters of the circuit. In addition each of the individual repeaters in the circuit may be cut in or removed from the circuit without having any adverse effect on the operation of the remaining components.

Panel #6 is used in a similar manner in conjunction with circuits, such as wind indicating, propeller revolution, engine order, underwater log, and propeller order.

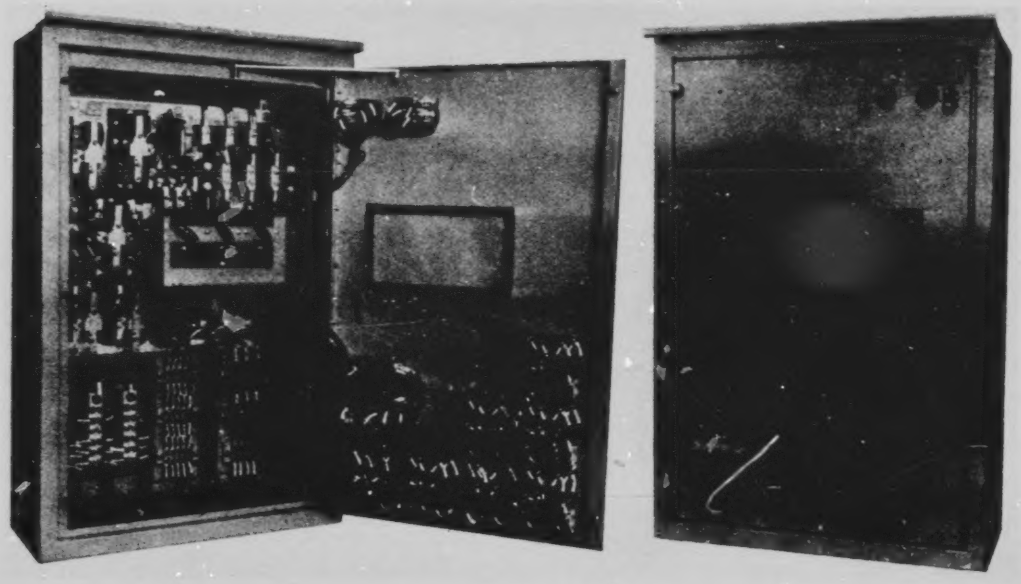
Located on the ACO section are a bank of type SR switches which are used to isolate the various speaker groups of the General Announcing System circuit 1MC. The General Chemical and Collision Alarms contact makers may also be isolated at these panels.

Fuses are installed on these panels to isolate the supplies of the gyro compass roll and pitch synchro signal amplifiers, and the engine room indicator lights of the General, Chemical, and Collision Alarms.

LOCAL IC SWITCHBOARDS

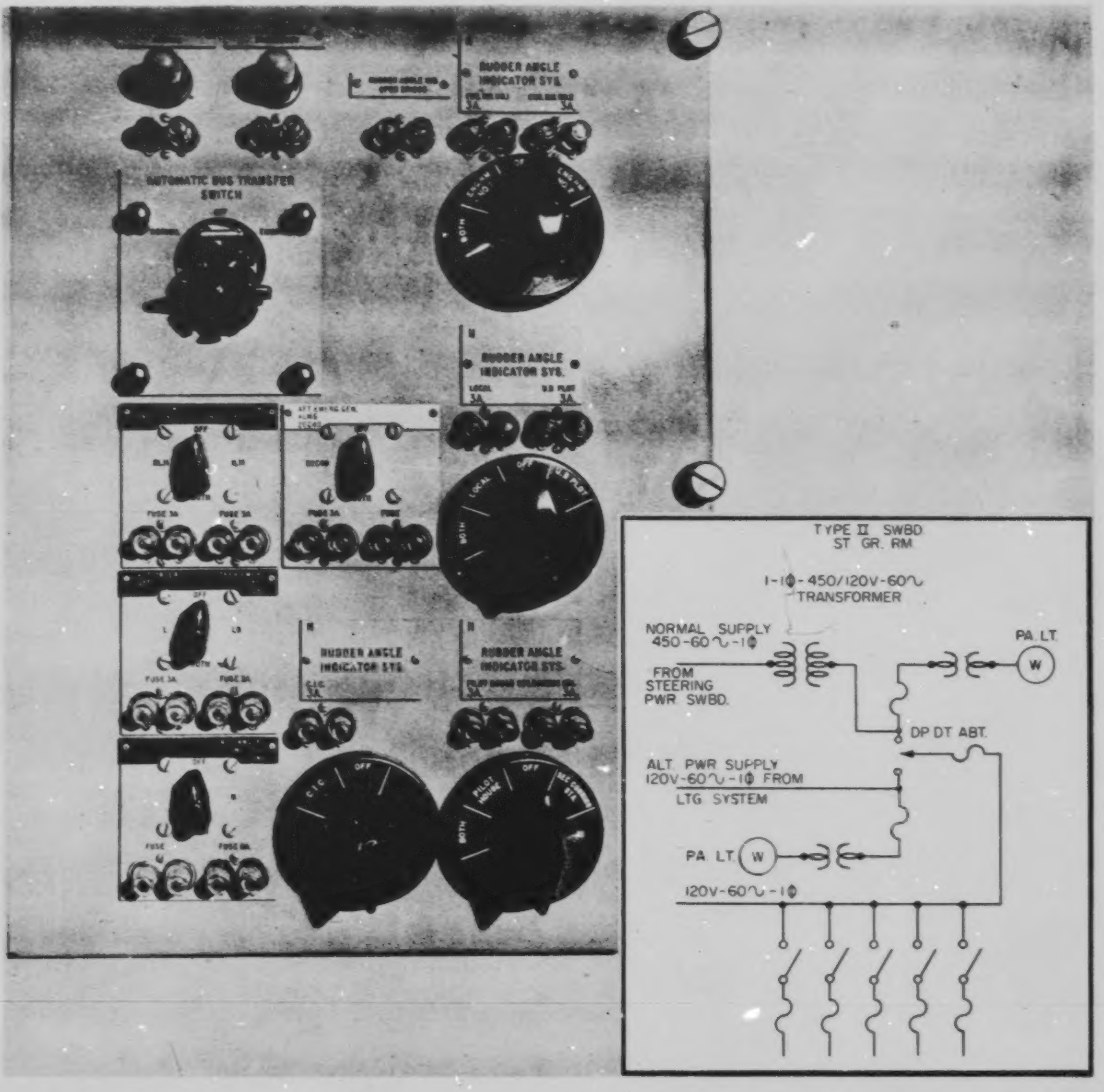
In order to facilitate better local control over circuits vital to the operation of various spaces, local IC boards have been installed. Such boards are installed in many enginerooms and steering gear rooms.

These boards (fig. 4-8) receive their power from two sources; in the case of the engineroom boards the normal source of power is the nearest main IC switchboard, while alternate power is supplied from a local emergency lighting circuit. In the case of the steering gear room boards the normal source is usually from a local power panel located in the steering gear room, while the alternate source is again a local emergency lighting circuit. Local IC switchboards use as their primary source of power, 120-volt single-phase or three-phase a-c, dependent upon their individual requirements. Automatic bus transfer



140.66

Figure 4-8.—Local IC switchboards.


AUTOMATIC BUS TRANSFER SWITCH
RUDDER ANGLE INDICATOR SYS.
3A
BOTH
LOCAL
OFF
C.I.C.
PILOT HOUSE
TYPE II SWBD
ST GR RM
1-1Φ-450/120V-60∿
TRANSFORMER
NORMAL SUPPLY
450-60∿-1Φ
FROM
STEERING
PWR SWBD.
PA LT
W
DP DT ABT.
ALT PWR SUPPLY
120V-60∿-1Φ FROM
LTG SYSTEM
PA LT
W
120V-60∿-1Φ

140.18

Figure 4-9. — Local IC **switchboard**, steering gear room.

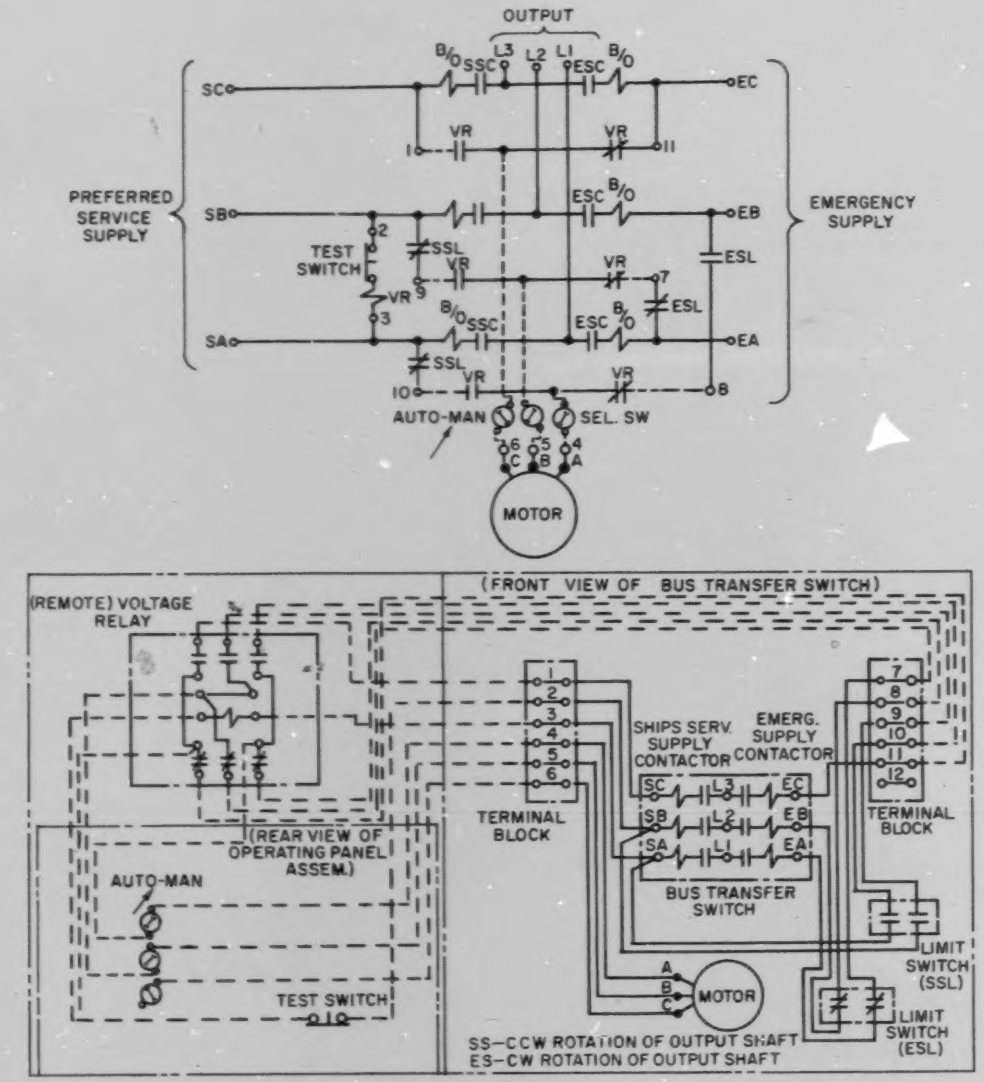
devices and indicator lights are included in all current applications.

Circuits which may be found on these local switchboards include the rudder order system, steering emergency system, rudder angle indicator, salinity indicator system, turbogenerator alarm, valve position indicator, and turbine alarm system.

A local IC switchboard (fig. 4-9), is usually installed in each steering gear room to energize all circuits associated with steering such as the steering-order and rudder-angle indicator systems. The normal supply for this switchboard is from the steering-power transfer switchboard through a local transformer. An alternate supply is taken from a local emergency lighting circuit to provide power if the normal supply is lost, because manual or emergency steering gear is provided in case of power failure to the steering power switchboard.

Automatic Bus Transfer Devices

The automatic bus transfer device installed in the local IC switchboard is designed to transfer a load, in this case the board, from one source of supply which has failed to an alternate source which remains energized. The model A3 and A2 units, described below, are two of


OUTPUT
L3
L2
L1
B/O
SSC
ESC
B/O
SC
EC
VR
VR
1
11
PREFERRED SERVICE SUPPLY
SB
ESC
B/O
EB
EMERGENCY SUPPLY
2
TEST SWITCH
SSL
VR
VR
9
7
ESL
ESL
VR
3
B/O
SSC
ESC
B/O
SA
EA
SSL
VR
VR
10
8
AUTO-MAN
SEL. SW
6
C
5
B
4
A
MOTOR
(FRONT VIEW OF BUS TRANSFER SWITCH)
(REMOTE) VOLTAGE RELAY
1
2
3
4
5
6
TERMINAL BLOCK
SHIPS SERV. SUPPLY CONTACTOR
EMERG. SUPPLY CONTACTOR
SC
L3
EC
SB
L2
EB
SA
L1
EA
7
8
9
10
11
12
TERMINAL BLOCK
(REAR VIEW OF OPERATING PANEL ASSEM.)
AUTO-MAN
TEST SWITCH
BUS TRANSFER SWITCH
LIMIT SWITCH (SSL)
A
B
C
MOTOR
LIMIT SWITCH (ESL)
SS—CCW ROTATION OF OUTPUT SHAFT
ES—CW ROTATION OF OUTPUT SHAFT

140.68

Figure 4-10.—Schematic and wiring diagram of A-3 ABT.

the more recent devices used to perform this function.

AUTOMATIC BUS TRANSFER MODEL A3.—The 300-ampere A3 units is currently being employed on large IC switchboards. The unit, pictured in figure 4-4, is designed to transfer a load from a preferred source to an alternate source of power in the event of a voltage failure in the preferred source, and to further retransfer upon restoration of the preferred source. With this type of unit the load is connected at all times to the preferred source as long as there is preferred voltage present at that source.

The contactor is motor operated but there is a means provided for manual operation of the unit. In this manner the desired source or the "off" position may be selected, regardless of the voltage present.

The unit is designed for 450-volt 3-phase operation in which the contactor consists of two three-pole cam-operated contactors for main line connection, two auxiliary cam-operated two-pole switches for control circuitry, a motor and a reduction gear for automatic operation, and a handwheel for manual operation.

Manual operation of the unit is accomplished by positioning the selector switch to the MANUAL position which disengages the motor enabling the operator to engage the handwheel. The handwheel is pushed in for engagement and then turned in the proper direction as indicated on the glass-inclosed pointer.

Automatic operation of the A3 takes place when the selector switch is in the AUTOMATIC position (fig. 4-10). Assuming that the preferred voltage drops to within the 264/308 volt range, the voltage relay VR becomes deenergized allowing its contacts to assume their normal position as shown. This permits the three-phase line from the emergency supply to be completed to the motor, resulting in a clockwise rotation of the motor and cam assembly. This rotation, which opens ship's service supply contactor contacts (SCC) and closes emergency supply contacts (ESC), is visible through the sight glass in front of the position indicator. When the cam has rotated to a predetermined position, the normally closed contacts of the Emergency Supply Limit Switch (ESL) open, disconnecting the motor from the line and completing the load transfer.

Automatic retransfer is accomplished when the preferred supply returns to the 374/418 volt range energizing the voltage Relay Coil (VR) which opens its normally closed contacts and closes its normally open contacts, thereby closing the circuit to the motor from the ship's service supply (normal). Counterclockwise rotation of the motor results in rotation of the cam and a change in the position indicator. Presently the Ship's Service Supply Contacts (SSC) close and the Emergency Supply Contacts (ESC) open. Rotation to a predetermine limit results in the opening of the Ship's Supply Limit Switch (SSL) disconnecting the motor from the line and completing the retransfer.

Provision is also made for testing the unit through the manipulation of the Test switch.

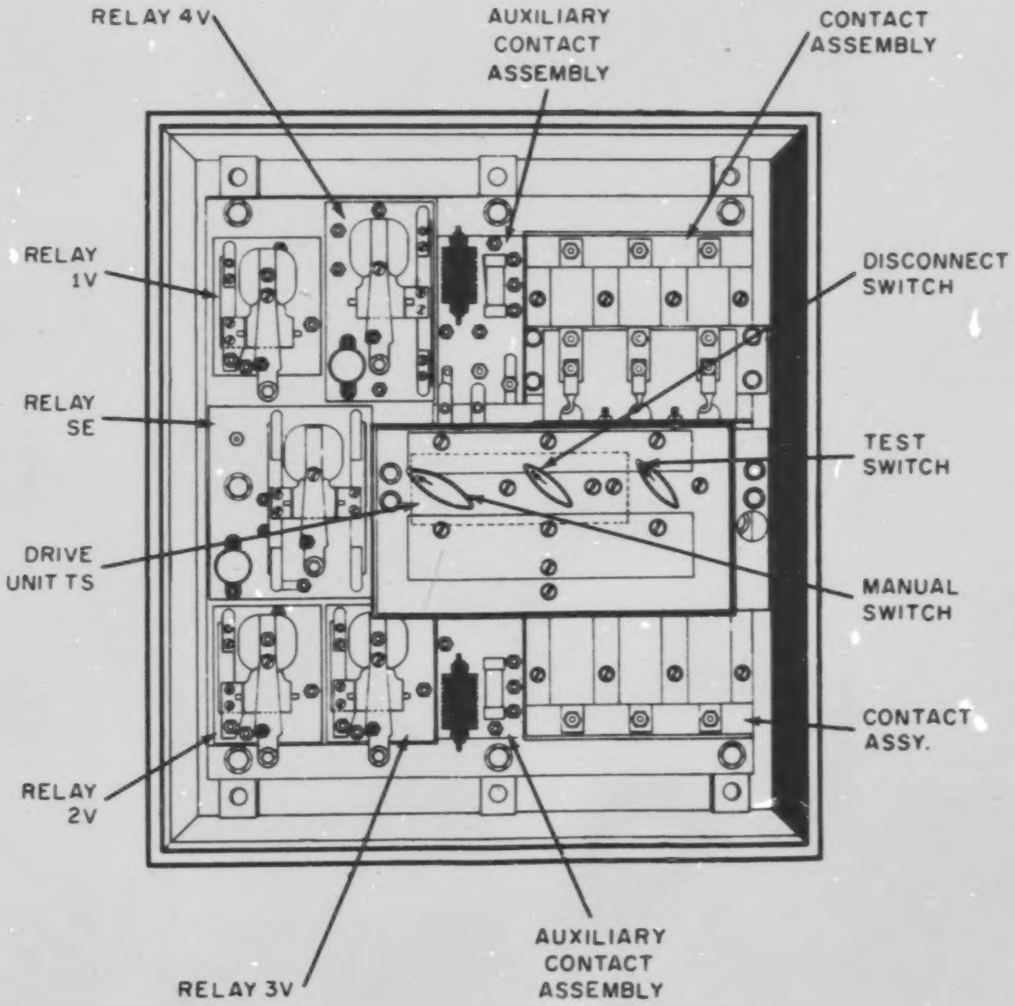
AUTOMATIC BUS TRANSFER MODEL A2.—The A 2 Model automatic bus transfer unit is designed to handle smaller loads and operate on 120-volt, 60-hertz circuits. Units of this type are currently being employed on local IC switchboards of the engineroom and steering gear room type, previously discussed. This unit may be used on single- or 3-phase circuits. For purposes of explanation the 3-phase unit will be discussed.

The A2 ABT (fig. 4-11) is designed to transfer automatically from normal to emergency supply upon a decrease in voltage to within the 81/69-volt range across any two of its three phases. Upon restoration of the voltage to the range of 98/109 volts the unit is adjusted to retransfer to the normal source of supply. An intentional time delay is included in the circuitry of from 0.3 to 0.5 seconds for both transfer and retransfer to allow for surges in line voltage and short duration losses in power.

The A2 unit is readied for manual operation by placing the control disconnect in the manual position and operating the manual handle (fig. 4-12).

Automatic operation is accomplished when the normal supply voltage drops to the dropout range and relay 1V, 2V, and 3V drop out. Contact 1 Val opens disconnecting relay SE. After a time delay of from 0.3 to 0.5 seconds, relay SE opens closing its SEb1 and SEb2 contacts and energizing relay 4V from the emergency source. Contact 4 Val in closing connects the emergency source to coil TS of the transfer switch which in turn operates, transferring the load to the emergency source.

Presently, contacts TSa4 and TSa5 open disconnecting coil TS from its operating circuit. TS is now held in the operated condition


RELAY 4V
AUXILIARY CONTACT ASSEMBLY
CONTACT ASSEMBLY
RELAY 1V
DISCONNECT SWITCH
RELAY SE
TEST SWITCH
DRIVE UNIT TS
MANUAL SWITCH
CONTACT ASSY.
RELAY 2V
AUXILIARY CONTACT ASSEMBLY
RELAY 3V

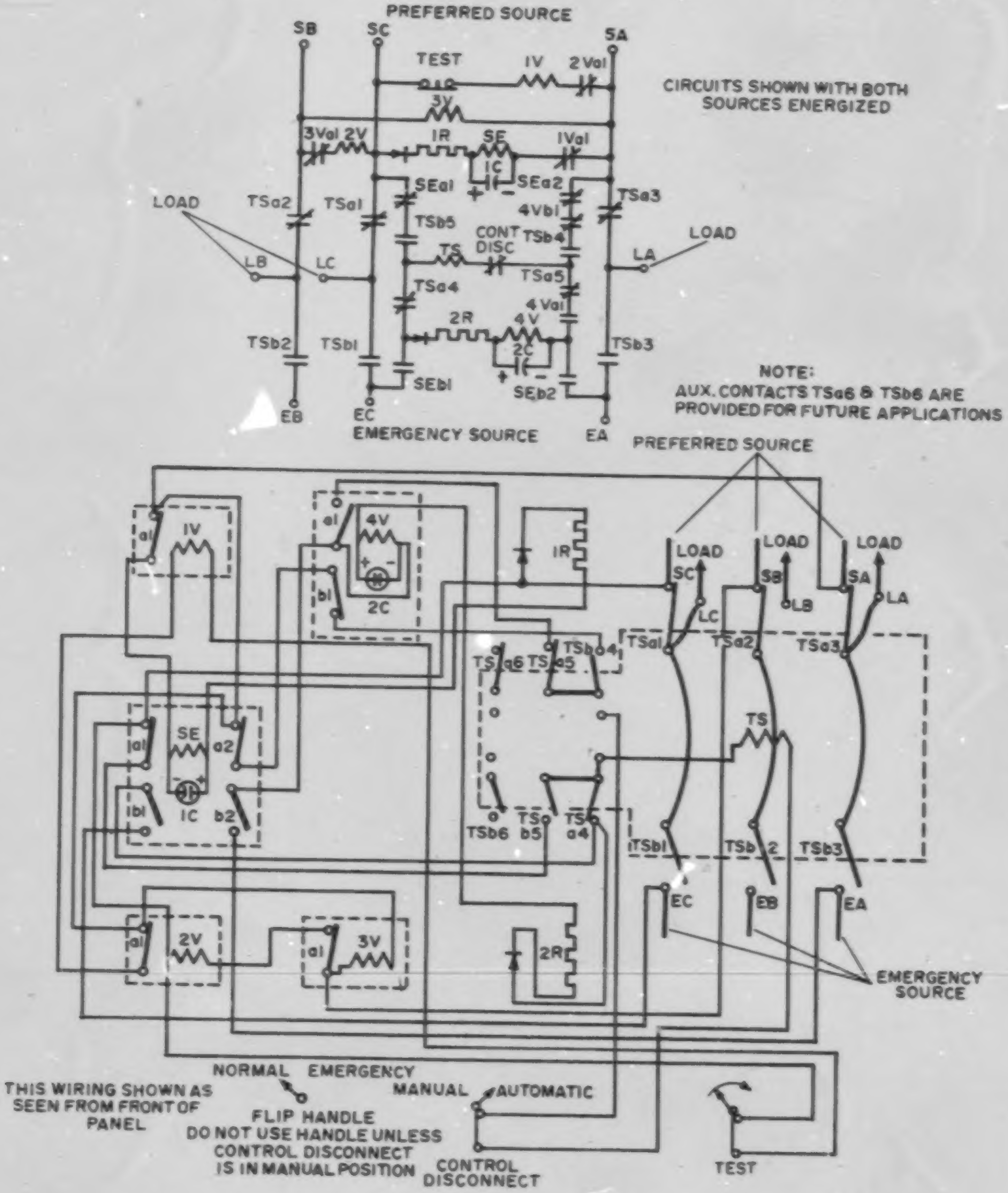
140.70

Figure 4-11.—Pictorial view of A-2 ABT.

mechanically, however and the transfer is now complete to the emergency supply.

Upon restoration of the normal power to the selected range the retransfer is begun by the energizing of relays 1V, 2V, and 3V which close energizing relay SE. Contacts SEb1 and SEb2 now open, disconnecting relay 4V from the emergency source. After the time delay, relay 4V opens, closing its 4Vb1 contact and completing the normal supply circuit to the transfer switch coil, TS, which again operates transferring the load back to the normal supply. Presently the transfer coil contacts TSb4 and TSb5 open, disconnecting the coil from the circuit. The coil is again mechanically held and the retransfer is now complete.

Care must be exercised when testing the ABT units to ensure that they do not include in their load vital and sensitive electronic circuitry which will be adversely affected by the loss and almost instant return of power. As in other tests, IC Electricians must ensure that all other groups are informed of the tests to be performed.


PREFERRED SOURCE
SB
SC
SA
TEST
1V
2Val
3V
CIRCUITS SHOWN WITH BOTH SOURCES ENERGIZED
3Val
2V
1R
SE
1Val
1C
SEa1
SEa2
LOAD
TSa2
TSa1
TSa3
4Vb1
TSb5
CONT DISC
TSb4
LB
LC
TS
LA
TSa5
TSa4
4 Va1
2R
4V
2C
TSb2
TSb1
TSb3
SEb1
SEb2
EB
EC
EA
EMERGENCY SOURCE
NOTE:
AUX. CONTACTS TSa6 & TSb6 ARE PROVIDED FOR FUTURE APPLICATIONS
PREFERRED SOURCE
a1
b1
LOAD
SC
SB
SA
LC
LB
LA
TSa6
TSa5
TSb4
TSb6
TSb5
TSa4
TSa1
TSa2
TSa3
TSb1
TSb2
TSb3
EMERGENCY SOURCE
a2
b2
THIS WIRING SHOWN AS SEEN FROM FRONT OF PANEL
NORMAL
EMERGENCY
MANUAL
AUTOMATIC
FLIP HANDLE
DO NOT USE HANDLE UNLESS CONTROL DISCONNECT IS IN MANUAL POSITION
CONTROL DISCONNECT
TEST

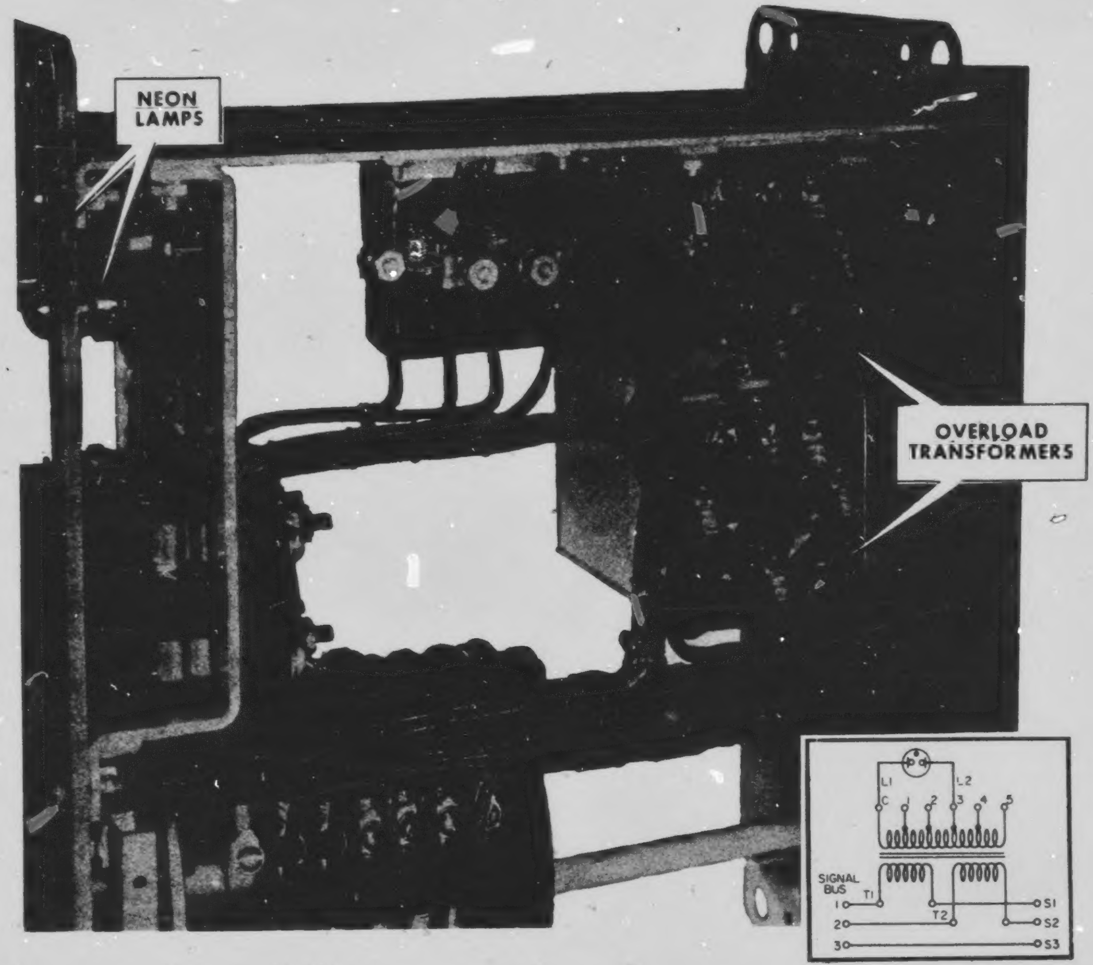
140.69

Figure 4-12.—Schematic and wiring diagram of A-2 ABT.

OVERLOAD INDICATORS

Recent designs of ACO sections are provided with synchro overload transformers. These transformers are in series with the secondary connections of selected synchro torque indicators to provide immediate information to operating personnel regarding a casualty so that the damaged instruments can be disconnected quickly by operating the associated switches. It is also necessary in each case to fuse the primary wires. Otherwise, a short in one indicator might blow the main fuses of the circuit, and no power would be available to operate the overload indicators to show the faulty circuit.

An overload transformer (fig. 4-13) consists of two primary windings, each in series with



55.317

Figure 4-13.—Synchro overload transformer.

one leg of the synchro stator wires. The secondary winding is connected to a small neon lamp (fig. 4-13) mounted on the face of the switchboard. The overload transformer is a current-sensitive device. It is arranged so that when the sum of the currents in the stator circuits to a particular synchro exceeds a predetermined amount, a neon lamp glows.

The synchro stator is in series with the primary coils of the transformer. An increase of current in the primary winding of the transformer will increase the voltage between the secondary terminals of the transformer.

The secondary of the transformer has numerous taps to provide a wide range of voltages for a given current.

The transformer may be used under different load currents. However, the tap used is dependent on the breakdown voltage of the neon lamp.

The principal difference between the operation for IC synchro circuits and for FC circuits is that for IC synchro circuits the overload transformers are usually set to provide a much greater relative displacement between transmitter and indicator before the overload lamp lights. FC synchro circuits are usually precision systems in which a relatively slight displacement between a transmitter and indicator may involve a serious error. Most IC circuits are generally used for the transmission of a relatively small number of orders, and a displacement between transmitter and indicator is not serious until sufficiently great to cause an incorrect order to appear at the indicator.

Operating personnel of IC switchboards should be very cautious when operating switches to disconnect indicators, particularly on vital circuits such as the engine order system. When practicable, operating personnel should investigate before operating the switch, as the overload indication may be a result of too low a setting on the overload transformer.

Energizing a circuit by means of a transfer switch generally results in a flash on the associated overload light, which is caused by the momentary displacement between the transmetter and receiver. Such indications are normal and show that the system is operating properly. Continual flashing, however, should be investigated.

The overload transformers are designed to operate with neon lamps for which the breakdown voltage is 52.5 volts a-c and 74 volts d-c. As previously stated, the breakdown voltage of neon lamps varies over a wide range. Any variation in this breakdown voltage is equivalent to changing a transformer tap. Replacement lamps, therefore, should be selected by measuring the breakdown voltages until a lamp is found that conforms approximately to the values given.

INDICATOR LIGHTS

The indicator lights on IC switchboards normally use two 6-volt lamps because 120-volt lamps are not suitable for the vibration and shock conditions encountered aboard ship. A-c applications require transformers, whereas d-c applications require resistors to furnish the necessary voltage. The a-c indicator lights are provided with integral transformers for either 120-volt or 450-volt applications. D-c indicator lights are provided with separate resistors.

Globes of various colors are required for specific applications.

SHIP'S SERVICE POWER DISTRIBUTION SYSTEM

The ship's service power distribution system is the electrical system that normally supplies power to the ship's equipment and machinery. The switchboards and associated generators are usually located in separate engineering spaces to minimize the possibility that a single hit will damage more than one switchboard.

The ship's service generator and distribution switchboards are interconnected by switches and cables, designated bus ties, because they tie together the buses of different switchboards. Thus, any ship service switchboard can be connected to feed power from its generators to one or more of the other switchboards. The bus ties may also be used to connect two or more switchboards so that the generators can be operated in parallel (or the switchboards can be isolated for split plant operation).

Power distribution is direct from the ship service generator and distribution switchboards to large and important loads, such as the main IC switchboard, steering gear, the gun turrets, and to loads near the switchboard. In large installations power distribution to other loads is from the generator and distribution switchboards or switchgear groups to load centers, to distribution panels, and to the loads or directly from the load centers to the loads.

On certain new construction, such as aircraft carriers, a system of zone control of the ship's service and emergency distribution is provided, wherein the ship is divided into areas generally coinciding with the fire zones of the damage control system. The system establishes a number of vertical zones, each of which contains one or more load center siwtchboards supplied through bus feeders from the ship's service switchgear group. A load center switchboard supplies power to the electrical loads within the electrical zone in which it is located. Thus, zone control is provided for all power within the electrical zone. The emergency switchboards may supply more than one zone, the number of zones depends on the number of emergency generators installed.

The majority of a-c power distribution systems in naval ships are 450-volt, 3-phase, 60-hertz, 3-wire systems.

The ship service generator and distribution switchboards are interconnected by bus ties so that any switchboard can be connected to feed power from its generators to one or more of the other siwtchboards. Th bus ties also connect tow or more switchboards so that the generator plants can be operated in parallel. In large installations (fig. 4-14a) distribution to loads is from the generator and distribution switchboards or switchgear groups to load centers, to distribution panels, and to the loads, or directly from the load centers to some loads.

On some ships, such as large aircraft carriers, a system of zone control of the ship service and emergency distribution is provided. Essentially, the system establishes a number of vertical zones, each of which contains one or more load center switchboards supplies through bus feeders from the ship service switchgear group. A load center switchboard supplies power to the electrical loads within the electrical zone in which it is located. Thus, zone control is provided for all power within the electrical zone. The emergency switchboards may supply more than one zone, the number of zones depends on the number of emergency generators installed.

In small installations (fig. 4-14b), the distribution panels are fed directly from the generator and distribution switchboards. he distribution panels and load centers (if any) are located centrally with respect to the loads that they feed. This arrangement simplifies the installation and requires less weight, space, and equipment than if each load were connected to a switchboard.

At least two independent sources of power are provided for selected vital loads. The distribution of this dual supply is accomplished in several ways: by a normal and an alternate ship service feeder; normal ship service feeder and an emergency feeder; or normal and alternate ship service feeder and an emergency feeder.

A-C SWITCHBOARDS

A-c switchboards may consist of a single section or of several sections physically separated and connected by cables to form a switchgear group. This arrangement of sections provides greater resistance to damage. It also provides a means for localizing damage, and removal of a damaged section for repairs or replacement.

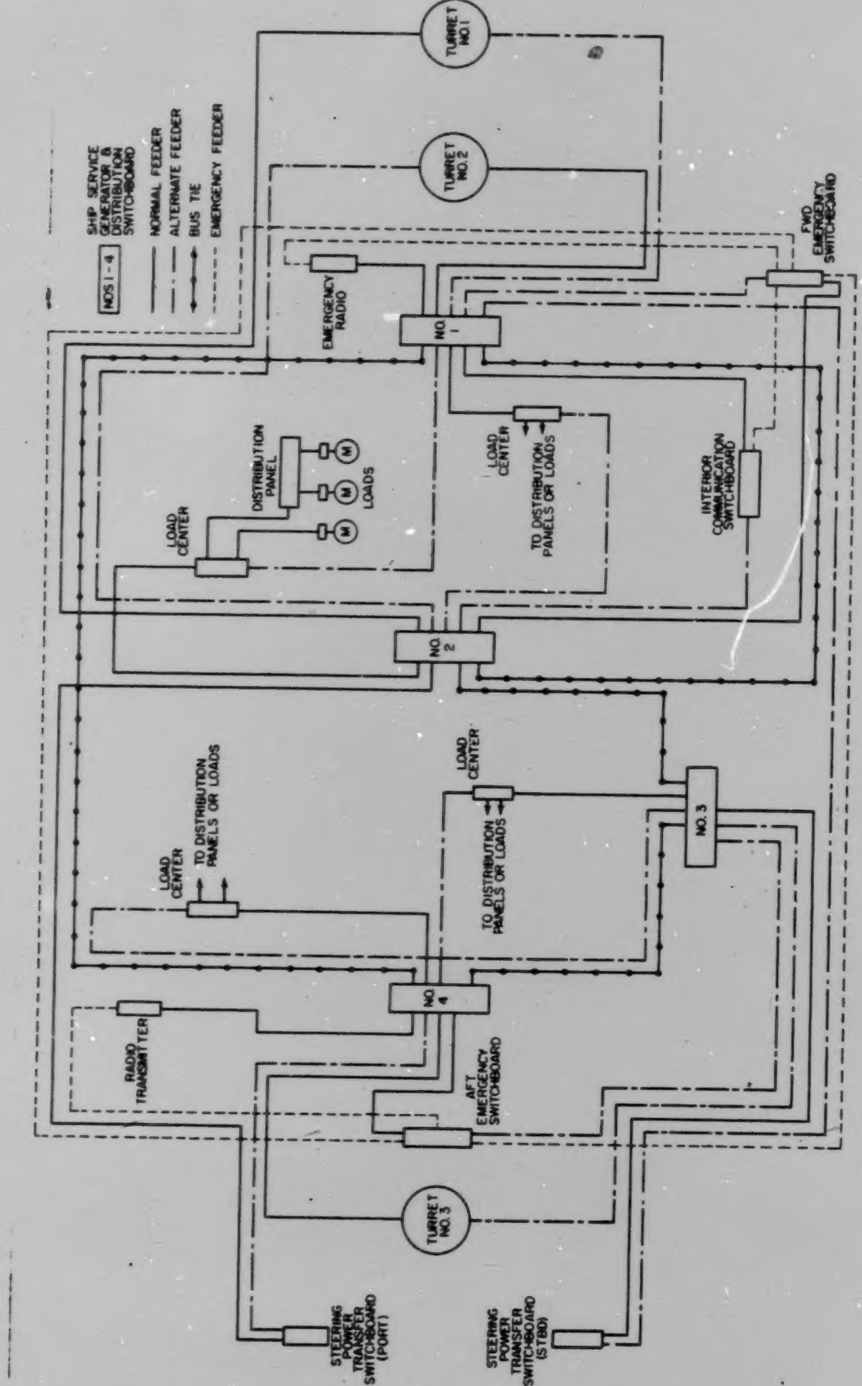
BUS-TRANSFER EQUIPMENT

Bus-transfer equipment is installed at load centers, distribution panels, or loads that are fed by both normal and alternate and/or emergency feeders. This equipment is used to select either the normal or alternate source of the ship's service power, or to obtain power from the emergency distribution system if an emergency distribution system feeder is also provided.

Automatic bus-transfer equipment is used for loads that require two power supplies, except for auxiliaries that are used when lighting off the engineering plant and fire pumps, which have manual bus-transfer equipment. On the steering power switchboard, which is provided with anormal, alternate, and emergency power supply, manual bus-transfer equipment is used to select between the normal and alternate supplies, and automatic bus-transfer equipment is used to select between the ship service and emergency supplies.

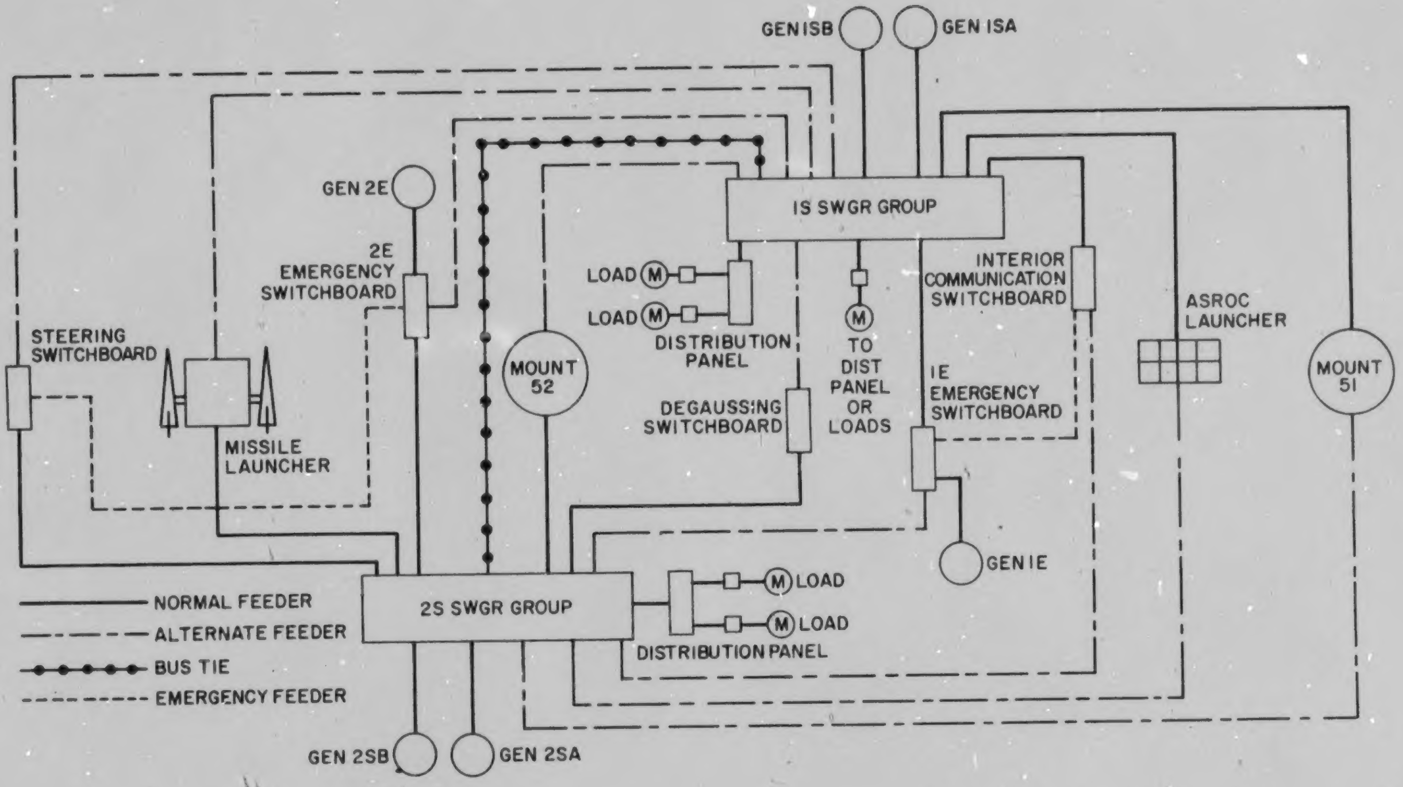
LIGHTING

The lighting circuits are supplies from the 120-volt secondaries of 450/120-volt transformer banks connected to the ship service power system. In large ships the transformer banks are installed in the vicinity of the lighting distribution panels located at some distance from the generator and distribution switchboards. In small ships the transformer banks


NOS 1-4
SHIP SERVICE GENERATOR & DISTRIBUTION SWITCHBOARD
NORMAL FEEDER
ALTERNATE FEEDER
BUS TIE
EMERGENCY FEEDER
TURRET NO.1
TURRET NO.2
FWD EMERGENCY SWITCHBOARD
EMERGENCY RADIO
NO. 1
LOAD CENTER
TO DISTRIBUTION PANELS OR LOADS
INTERIOR COMMUNICATION SWITCHBOARD
DISTRIBUTION PANEL
M
M
M
LOADS
LOAD CENTER
NO. 2
LOAD CENTER
TO DISTRIBUTION PANELS OR LOADS
NO. 3
LOAD CENTER
TO DISTRIBUTION PANELS OR LOADS
NO. 4
RADIO TRANSMITTER
AFT EMERGENCY SWITCHBOARD
TURRET NO.3
STEERING POWER TRANSFER SWITCHBOARD (PORT)
STEERING POWER TRANSFER SWITCHBOARD (STBD)

55.54.2

Figure 4-14A.—Power distribution in a large combatant ship.


GEN ISB
GEN ISA
IS SWGR GROUP
GEN 2E
2E EMERGENCY SWITCHBOARD
LOAD
LOAD
DISTRIBUTION PANEL
TO DIST PANEL OR LOADS
INTERIOR COMMUNICATION SWITCHBOARD
ASROC LAUNCHER
MOUNT 51
STEERING SWITCHBOARD
MISSILE LAUNCHER
MOUNT 52
DEGAUSSING SWITCHBOARD
IE EMERGENCY SWITCHBOARD
GEN IE
2S SWGR GROUP
LOAD
LOAD
DISTRIBUTION PANEL
NORMAL FEEDER
ALTERNATE FEEDER
BUS TIE
EMERGENCY FEEDER
GEN 2SB
GEN 2SA

65.54.1

Figure 4-14B. – Power distribution in a guided missile destroyer.

are located near the generator control and distribution switchboards and energize the switchboard buses that supply the lighting circuits.

The lighting distribution system feeders, mains, and submains are 3-phase circuits; the branches are single-phase circuits. The single-phase circuits are connected so that under operating conditions the single-phase loads on the 3-phase circuits are as nearly balanced as possible.

PHASE SEQUENCE

Phase identification is denoted by the letters, A, B, and C, in a 3-phase system. Switchboard and distribution panel bus bars and terminals on the back of switchboards are marked to identify the phase with the appropriate letters, A, B, or C.

The phase sequence in naval vessels is ABC; that is, the maximum positive voltages on the three phases are reached in the order: AB, BC, and CA. Phase sequence determines the direction of rotation of 3-phase motors. Reversal of the phase sequence reverses the direction of rotations of electric motors. The phase sequence of the power supply throughout a ship is always ABC, irrespective of whether power is supplied from any of the switchboards or from the shore power connection. This condition ensures that 3-phase, a-c motors will always run in the correct direction.

SHORE POWER CONNECTION

A shore power connection is provided at, or near a suitable weather deck location to which portable cables from the shore or from a vessel alongside can be connected to supply power for the ship's distribution system when the ship service generators are not in operation. This connection also can be used to supply power from the ship's service generators to a ship alongside. The shore power circuit breaker is located on the after switchboard on most destroyers. The breaker connects the shore power to the bus tie system.

MULTIPURPOSE POWER OUTLETS

Multipurpose power outlets are provided to supply 450-volts, 3-phase power for portable hoists; portable tools that require 450-volt power, portable welding units for repair, maintenance, and damage repair purposes, including underwater welding and cutting; and portable submersible pumps. The multipurpose power outlets are of the grounded type and are used with grounded plugs and cables having a ground wire that grounds the metallic case and exposed metal parts of the tool or equipment when the plug is inserted in receptacle. The ground wire provides a conducting path of low resistance between the metal housing of the tool and the ship's structure. In the event of a casualty to the insulation of the tool, the ground wire will shunt the operator, thereby protecting him from electrical shock.

These outlets are located so that two portable pumps can be operated in any compartment by using 75 feet of cable for each pump. The outlets are fed from battle power distribution panels. A minimum number of outlets are fed from any one panel to provide as great a diversity of supply as possible. An adapter is provided with the 75-foot extension cables for making connections to the casualty power system if power is lost from the outlets.

D-C POWER

D-c power in ships with a-c power systems is furnished either by oversize exciters for the ship's service generators, by separate motor-generator sets, or by rectifiers. The principal d-c loads are carbon-arc searchlights, degaussing installations, battery charging stations, and the interior communications and fire control system. The use of the 24-inch, carbon-arc searchlight has been discontinued aboard most ships with a consequent reduction in the d-c power requirements. Rectifier power supplies are used as d-c power sources in the latest ships provided with a-c power systems.

EMERGENCY POWER DISTRIBUTION SYSTEM

The emergency power distribution system is provided to supply an immediate and automatic source of electric power to a limited number of selected vital loads in the event of failure of the normal ship service power distribution system. The system, which is separate and distinct from the ship service power distribution system, includes one or more emergency switchboard is supplied by its associated emergency generator. The emergency feeders run from the emergency switchboards (figs. 4-14a and b) and terminate in manual or automatic bus transfer equipment at the distribution panels or loads for which emergency power is provided. The emergency power distribution system is a 450-volt, 3-phase, 60 hertz system with transformer banks at the emergency distribution switchboards to provide 120-volt, 3-phase power for the emergency lighting system.

The emergency generators and switchboards are located in separate spaces from those containing the ship service generators and distribution switchboards. The emergency feeders are located near the centerline and higher in the ship (above the waterline) than the normal and alternate ships service feeders. This arrangement provides for horizontal separation between the normal and alternate ship's service feeders and vertical separation between these feeders and the emergency feeders, thereby minimizing the possibility of damaging all three types of feeders simultaneously.

When the ship service plants are secured and shore or tender power is not available, the emergency generators can "feed back" power to either switchgear group by means of a bus transfer selector switch on the emergency switchboards. The bus transfer selector switch when placed in the manual position, allows manual operation of the circuit breakers on the emergency switchboards. While the bus transfer selector switch is in the normal preferred or alternate preferred position, the three circuit breakers on the emergency switchboards are interlocked and only one of them can be closed at a time. The feedback circuits should only be used in special circumstances such as to supply power to the ship service bus for starting the ship service plant. When the feedback provision is in use, do not overload the emergency generators. The feed-back circuits must NEVER be used to parallel the emergency generators with each other, with the ship service generators, or with shore power.

PREFERRED AND ALTERNATE SOURCES OF POWER

The emergency switchboard is connected by cables, called feeders, to at least one and usually to two different ship service switchboards. One of these switchboards is the PREFERRED, or normal, source of ship service power for the emergency switchboard and the other is the ALTERNATE source. The emergency switchboard and distribution system are normally energized from the preferred source of ship service power. If this source of power should fail, bus-transfer equipment automatically transfers the emergency switchboard to the alternate source of the ship service power. If both the preferred and alternate sources of ship's service power fail, the diesel-driven emergency generator starts automatically, and the emergency switchboard is automatically transferred to the emergency generator.

When the voltage is restored on either the preferred or alternate source of the ship service power, the emergency switchboard is automatically retransferred to the source that is available or the preferred source if voltage is restored on both the preferred and alternate sources. The emergency generator must be manually shut down. Hence, the emergency switchboard and distribution system are always energized either by a ship service generator or by the emergency generator. Therefore, the emergency distribution system can always supply power to a vital load if both the normal and alternate sources of the ship service power to this load fail. The emergency generator is not started if the emergency switchboard can receive power from a ship service generator.

FEEDBACK TIE

A switch and cable arrangement, designated a feedback tie, is provided in most ships. The feedback tie feeds power back to the ship service switchboard, thus a selected portion of the ship service switchboard load may be supplied from the emergency generator. This feature facilitates starting up the machinery after major steam alterations and repairs, and provides power to operate necessary auxiliaries and lighting during repair periods when shore power and ship service power are not available.

OPERATION OF A-C GENERATORS

The a-c generator may be operated separately as a single unit or in combination with other generator units in paralleling operation. The advantages of having generator sets paralleled together is that more current or power is available in a system, an electric load can be transferred without interruption of power, and that there is greater efficiency under a varying load condition. The basic requirements for paralleling are that the generators must be in phase with each other, have the same phase rotation (ABC), and have the same voltage and frequency.

NONPARALLEL OPERATION

The nonparallel operation of a single a-c generator consists of connecting the generator to a non-energized bus for operation. The generator should be inspected before starting for any machinery derangements that may be caused by operating or repair personnel. Routine checks and inspections are made during generator operation according to operating instructions.

The Machinist's Mate and Electrician's Mate have operating instructions to follow when operating generator equipment. Before starting and during idling (warmup time), there are many checks to be made. The EM must be sure he has positioned all switches in the correct position before starting the generator. After starting, he must check his instruments and gages for proper operation. Before connecting the generator to the bus he must be sure the generator is running at operating speed. He then manually adjusts the voltage and frequency to the correct rating and places the generator in automatic operation and again checks the voltage and frequency. When he is satisfied that all operating conditions are normal, he closes the generator circuit breaker connecting the generator to the bus and load. In some installations, it may be necessary to open certain power and lighting circuit breakers before connecting the generator to the bus so that the generator will not pick up the entire load at one time.

When the a-c generator is operating, the man on watch is required to note the voltage and frequency readings and adjust, when necessary, check warning lights, gage sight glasses, steam and vacuum gages, and be aware of lube oil alarms, unusual generator noises, vibrations, odors, and other abnormalities. He may be required to control the voltage manually during emergency operations.

To secure an a-c generator which is connected along to a bus, reduce the load on the generator as much as practicable by opening feeder circuit breakers on the power and lighting circuits. Trip the generator circuit breaker, turn the voltage regulator control switch to the manual position, and place the manual voltage control as far as it will go in the DECREASE VOLTAGE direction.

PARALLEL OPERATION

Parallel operation of a-c generators consists of connecting a generator to a bus that is already energized by one or more generators. Again, it is very important to follow the operating instructons.

On new construction "synchronizing monitors" are being used on 60-hertz ship service systems to prevent the paralleling of generators which are not synchronized. On systems using this type of monitoring, it is not possible to close the circuit breaker on the incoming generator unless the phase angle, frequency, and voltage are within predetermined limits as follows:

1. Phase angle between -30° and +40°.
2. Frequency difference less than 0.2 hertz.
3. Voltage difference less than 5%.

On this type of system, the above conditions must be met to complete the circuit breaker closing control circuit.

To synchronize generators for parallel operation, bring the incoming generator up to normal speed and voltage. Adjust the incoming generator frequency and voltage to that of the bus. Use the synchroscope to make the fine adjustment. In operation the synchroscope will rotate in one direction or the other. Adjust the speed of the generator by means of the governor motor control switch until the synchroscope rotates very slowly in the clockwise direction. Be certain that the voltages of the bus and the incoming generator are still equal, and close the generator circuit breaker just before the synchroscope pointer passes very slowly through the zero position (pointing vertically upward).

When synchronizing lamps are used instead of the synchroscope, close the circuit breaker just before the midpoint of the dark period of the lamps is reached. The midpoint of the dark period corresponds to the vertical position of the synchroscope pointer. Then turn the synchronizing switch to the OFF position.

When a-c generators are operated in parallel, the kilowatt and reactive kva load should be divided between them in proportion to the generator ratings. The desired division of the kilowatt load is obtained by adjusting the governor, which controls the gnerator speed. To balance the reactive kva load, the generator line currents should be equal for equally rated generators and divided in proportion to generator ratings for unequally rated generators. Where power factor meters are provided, the power factors for all generators in parallel should be equal. Equality of power factor or correct division of generator line currents is obtained by adjusting the voltage-adjusting rheostats of the voltage regulators.

WATCHSTANDING

During watchstanding there are a few simple operating rules which should be observed on all installations.

Watch the switchboard instruments. They show how the system is operating, reveal overloads, improper division of kilowatt load or of reactive current between generators operating in parallel, and other abnormal operating conditions. By reading these instruments the watchstander can detect the presence of a moderate over current or a power overload which, if allowed to remain, would cause the generators to overheat.

Keep the frequency (on a-c systems) and voltage at their correct values. Departure from either affects, to some extent at least, the operation of all equipment supplied with electric power. Low or high voltage has a pronounced effect on lights since low voltage results in a marked decrease in illumination, while high voltage materially shortens lamp life. The operation of vital electronic, interior communication, and fire control equipment is also seriously affected. This sensitive equipment requires careful adjustment of voltage regulators and prime mover governors to obtain satisfactory performance.

Use good judgment when reclosing circuit breakers after they have tripped automatically. If a circuit breaker trips immediately upon the first reclosure, it is desirable to investigate before again reclosing. The circuit breaker may, however, be closed a second time without investigation if the immediate restoration of power to the circuit is important and the interrupting disturbance when the breaker tripped was not excessive. Remember that repeated closing and tripping may result in damage to the circuit breaker and thereby increase the repair or replacement work needed to get the circuit back in operation again.

Use the hold-in device on circuit breakers only when absolutely necessary. The hold-in device enables an operator to hold a trip free circuit breaker closed when the current is in excess of the tripping value. The circuit breaker will open automatically as soon as the hold-in device is released if the current is above the tripping current. In an emergency it may be vitally important to obtain power even at the risk of burning out equipment. The hold-in device makes it possible to do this. However, when holding a circuit breaker closed, you deprive the circuit of protection against damage by excessive current, and the longer you hold the circuit breaker closed, the greater is the chance of permanent damage to circuits or equipment. A circuit breaker should never be held closed unless there is an emergency which justifies the risk.

Never parallel ship service generators until they have been brought into synchronism.

Never close the bus tie circuit breakers to parallel the buses on two energized switchboards until the buses have been brought into synchronism.

Never close the bus tie circuit breaker to restore power to a switchboard which has lost power because of failure of a local generator that was supplying power to the switchboard prior to the generator failure, unless the generator circuit breaker has first been tripped by hand, or unless it has been definitely established that the generator circuit breaker is in the open position.

Never parallel ship service generators with shore power except for the short interval required to transfer the load from one source of power to the other. Never parallel ship service generators with shore power of a different frequency such as 50 Hz. Never parallel with shore power without the use of synchroscope or synchronizing lights. On ships where a synchroscope is not provided for synchronizing between shore power and the bus, the generator breakers shall be opened first and then the shore power breaker shall be closed. On some ships, shore power may be connected to the bus tie with the bus tie breakers open and synchronizing can be accomplished across the bus tie breakers. When placing the shore power and the ships service generators in parallel, the normal synchronizing process is reversed. The incoming shore power is the controlling source and the voltage and frequency of the ship service generators must be made to match the shore power voltage and frequency. There are several precautions to be taken when paralleling with shore power in addition to the usual ones when paralleling two ship's service generators. The shore power connection phase rotation must be the same as the ship phase rotation. This is easily determined with a phase-sequence indicator. If there is to be more than one shore power connection and they are to be paralleled, the actual phases of the shore power should not only be in the same rotation but must be connected to match the ship's phases in order to avoid a short circuit through the ship's system. When paralleling with shore power for purposes of transferring the load, bring the ship's voltage up to the shore power voltage or as close thereto as possible. In some cases, the shore power voltage may be around 480 volts.

Increase the ship's generator to 480 volts. Now bring the ship's frequency to that of the shore power. Turn on the synchroscope, synchronize the ship's power with the shore power, and close the shore power breaker. Quickly transfer load to the shore power. Trip the ship service generator breakers.

Always check phase sequence before making connection to a shore power supply and be sure to make connections so that the phase sequence on the shore power will be A, B, C. If the shore power connection is made so that it gives the wrong phase sequence on the ship, motors will run in the wrong direction.

Never parallel an emergency generator with any other generator except on certain ships where the emergency generator also serves as a "standby set" and, as such, provisions have been made for paralleling with the ship service power system.

Always observe electrical safety precautions. Never adjust a ventilation opening for personal comfort of watchstanders to a position where spray or solid water entering the system through weather openings can be discharged onto switchboards, distribution panels, bus bars, or other electrical equipment.

Always operate switchboards and distribution system equipment as if no automatic protective devices were installed. Trouble will sooner or later be the inevitable consequence of careless and slipshod operating practices based upon the assumption that automatic protective devices either will prevent incorrect operation or will prevent damage from incorrect operation. They will not because they are not designed or intended to do so. The protective devices used with the distribution system are intended to afford protection against damage as a consequence of equipment failure, not of operator failure. The intelligence which is needed for the operation of the distribution system is not built into the system but must be furnished by the operator. You must, therefore, read and follow the instructions on warning plates and indicator lights, must know the system and operate it correctly, and must never depend upon automatic devices to keep you from making a mistake or to save you from the consequences of a mistake.

To secure an a-c generator that is operating in parallel with another generator or other generators: (1) turn the governor motor control switch of the generator being secured in the DECREASE SPEED direction and the governor motor control switch (or switches) of the other generator (or generators) in the INCREASE SPEED direction until all the load is shifted from the generator being secured, (2) trip the circuit breaker of the generator being secured, and (3) return the automatic voltage regulator control to the manual position, and the manual voltage control rheostat to the decrease voltage position.

CASUALTY POWER SYSTEM

The casualty power distribution system is provided for making temporary connections to supply electric power to certain vital auxiliaries if the permanently installed ship service and emergency distribution systems are damaged. The system is not intended to supply circuits to all the electrical equipment in the ship but is confined to the facilities necessary to keep the ship afloat and to get it away from a danger area. The system also supplies a limited amount of armament, such as antiaircraft guns and their directors, that may be necessary to protect the ship when in a damaged condition. The casualty power system for rigging temporary circuits is separate and distinct from the electrical damage control equipment, which consists of tools and appliances for cutting cables and making splices for temporary repairs to the permanently installed ship service and emergency distribution system.

The casualty power system includes portable cables, bulkhead terminals, risers, switchboard terminals, and portable switches. Portable cables in suitable lengths are stowed throughout the ship in convenient locations. The bulkhead terminals are installed in watertight bulkheads so that horizontal runs of portable cables can be connected on the opposite sides of the bulkhead terminal to transmit power through the bulkheads without the loss of water tight integrity. The risers are permanently installed vertical cables for transmitting power through decks without impairing the watertight integrity of the ship. A riser consists of a cable that extends from one deck to another with a riser terminal connected to each end for attaching portable cables.

Suitable terminals are provided at switchboards and some distribution panels for connecting portable cables at these points to obtain power from or supply power to the bus bars. Casualty power circuit breakers are installed at switchboards so that the terminals can be deenergized when the cables are connected. The portable switches are stowed in repair party lockers and are used when necessary for connecting and disconnecting the circuits. The locations of the portable cables, bulkhead terminals, and risers are selected so that connections can be made to many vital electrical auxiliaries from any of the ship's service or emergency generators. Casualty power cables should be rigged only when required for use, or for practice in rigging the casualty power system.

RIGGING AND UNRIGGING CASUALTY POWER CABLES

There are definite procedures that must be followed and safety precautions that must be observed in rigging casualty power. Only qualified personnel should do the actual connecting; however, the portable cables may be laid out by other personnel. Safety precautions require the man making the connections to wear rubber gloves, and to stand on a rubber mat or wear rubber boots while making connections. He is further required to test each casualty power riser or bulkhead terminal with a voltage tester before making a connecting. The portable cable connections for casualty power should always be made by first connection at the load, then working back to the source of power. In making casualty power connections at a load where there are not circuit breakers or transfer switches to interrupt the incoming feeder cable, it must be disconnected or cut at the equipment. It is quite possible that this cable may be damaged by the casualty which caused the loss of power, and such a damaged cable if energized would probably trip the casualty power circuit breakers. If not disconnected, this incoming feeder cable may be reenergized and present a hazard to personnel handling the casualty power cables. Care should be exercised in making all connections, to keep the phase sequence correct in a-c systems. If the load includes motors in either a-c or d-c systems, the connections should be made so as to include the motor controller in the circuit.

Casualty power cables should be tied to the overhead and high voltage signs should be attached at each connection. Also, it is common practice to pass the word over the ship's 1MC system, informing all hands to stand clear of the casualty power cables after they are energized.

Unrigging casualty power is also hazardous if not handled correctly. The recommended procedure is for the Electrician's Mate on the switchboard at the source of the casualty power supply to open the 225 or 250 ampere AQB circuit breaker behind the switchboard that supplies the system, and to remove both ends of the first cable nearest the source. After this has been done, both ends of the last cable in the system that connects to the load are disconnected and removed. The normal feeder or feeders may now be reenergized to the equipment, and the remainder of the casualty power cables are unrigged and restowed on the proper racks.

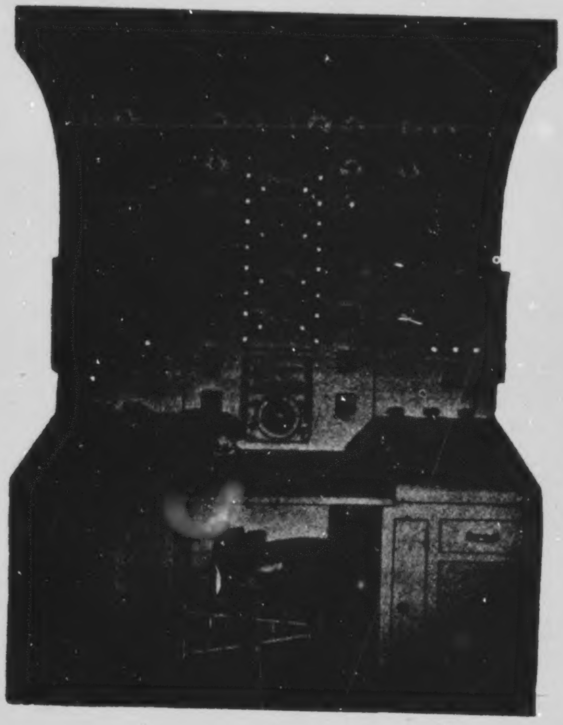
POWER DISTRIBUTION SWITCHBOARDS

A switchboard may consist of a single section or of several sections that are physically separated and are connected by cables to form a switchgear group. This arrangement provides sufficient separation between sections to minimize damage from shock, to LOCALIZE damage from fire, and to permit easy removal of damaged sections for repairs or replacement.

On dead-front switchboards the equipment is grouped to form a number of units each complete with a separate front panel and all the required apparatus, such as the a-c generator control unit a-c bus-tie unit, power distribution unit, and lighting distribution unit. The units are mounted on a common base.

CONTROL BENCHBOARD

A separate control benchboard (fig. 4-15) is provided in the switchgear groups for cruisers and aircraft carriers. This benchboard mounts generator control equipment, measuring instruments, and remote controls for some electrically operated equipment. This arrangement provides for a centralized control of the generators and major switching operations. The control benchboard in ships equipped with four ship's service switchgear groups is provided with a mimic bus (a small switchboard plan) that has indicating lights to show which generator circuit breaker and which bus-tie circuit breakers are closed



27.65.1
Figure 4-15. —Control benchboard.

throughout the ship. In ships not provided with control benchboards the metering and control equipments are mounted on the front panels of the units in the switchboards or switchgear groups.

SHIP'S SERVICE SWITCHBOARD

The ship's service switchboards in a destroyer consist of switchgear groups 1S and 2S, located in the forward and after enginerooms, respectively.

The forward ship's service switchgear group 1S is designated as the control switchboard because it is provided with instruments and governor control (for the forward generator) to allow for dividing the load. All paralleling of the generators is accomplished at the ship's service switchboard associated with the incoming generator.

The after ship's service switchgear group 2S is similar to the forward ship's service switchgear group and consists of the same number of corresponding designated panels.

Generator switchboards are equipped with meters to indicate the generator voltage, current, watts, frequency, and power factor. Synchroscopes and synchronizing lamps are provided for paralleling generators. Indicator lamps are provided for visual indication of the operating conditions of various circuits.

The frequency is controlled by the generator speed. The speed is automatically controlled by the governor of the prime mover. The governors for large machines can be set to the required speed by a governor motor controlled from the switchboard.

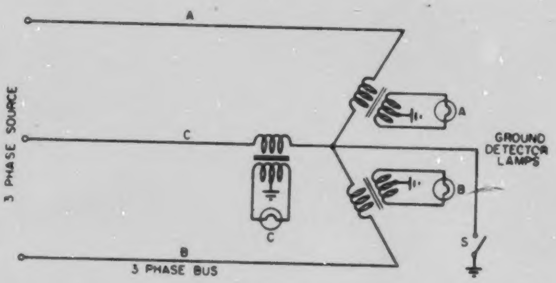
To prevent the generator from operating as a motor when running in parallel with other generators, the generator circuit breaker is equipped with a reverse power relay that trips the breaker and takes the generator off the line when power is fed from the line to the generator instead of from the generator to the line.

Protection against overspeed is provided in the governing mechanism of the prime mover.

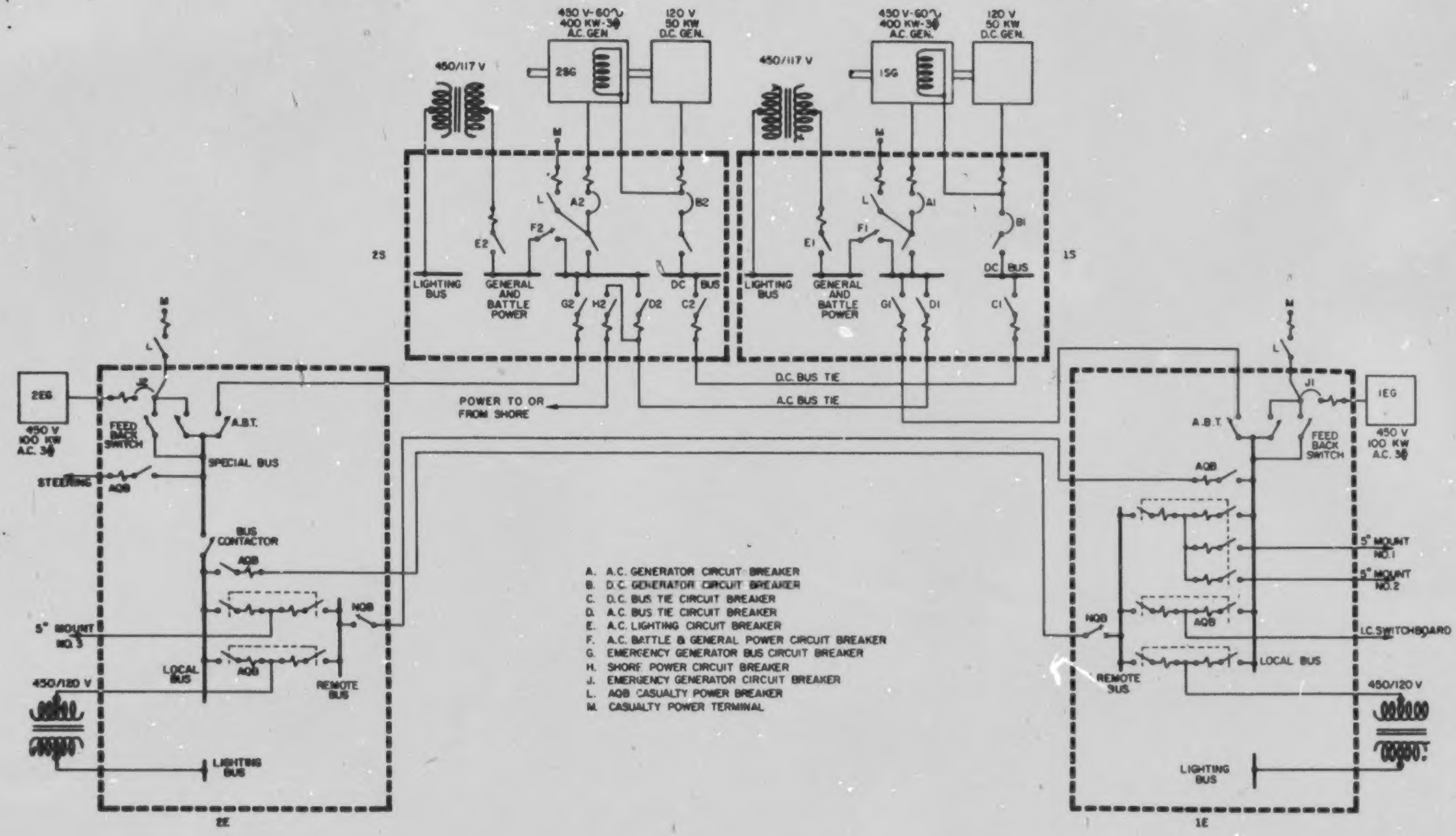
GROUND DETECTOR LAMPS

A set of three ground detector lamps (fig. 4-16) is connected (through transformers) to the main bus of each ship's service switchgear group and to the emergency bus, enabling the switchboard watch to check for grounds on any phase of the 3-phase bus.

To check for a ground, turn switch S on and observe the brilliancy of the three lights. If the lights are equally bright, no ground exits, and all lights receive the same voltage. For



77.172
Figure 4-16. —A-c ground detector lamp circuit.


450/117 V
450 V-60~ 400 KW-3φ A.C. GEN
2SG
120 V 50 KW D.C. GEN.
450/117 V
450 V-60~ 400 KW-3φ A.C. GEN.
1SG
120 V 50 KW D.C. GEN.
M
L
A2
B2
E2
F2
2S
LIGHTING BUS
GENERAL AND BATTLE POWER
DC BUS
G2
H2
D2
C2
A1
B1
E1
F1
1S
G1
D1
C1
2EG
450 V 100 KW A.C. 3φ
J2
FEED BACK SWITCH
A.B.T.
SPECIAL BUS
STEERING
AQB
BUS CONTACTOR
NQB
5" MOUNT NO.3
LOCAL BUS
REMOTE BUS
450/120 V
2E
D.C. BUS TIE
A.C. BUS TIE
POWER TO OR FROM SHORE
A. A.C. GENERATOR CIRCUIT BREAKER
B. D.C. GENERATOR CIRCUIT BREAKER
C. D.C. BUS TIE CIRCUIT BREAKER
D. A.C. BUS TIE CIRCUIT BREAKER
E. A.C. LIGHTING CIRCUIT BREAKER
F. A.C. BATTLE & GENERAL POWER CIRCUIT BREAKER
G. EMERGENCY GENERATOR BUS CIRCUIT BREAKER
H. SHORE POWER CIRCUIT BREAKER
J. EMERGENCY GENERATOR CIRCUIT BREAKER
L. AQB CASUALTY POWER BREAKER
M. CASUALTY POWER TERMINAL
1EG
450 V 100 KW A.C. 3φ
J1
5" MOUNT NO.1
5" MOUNT NO.2
I.C. SWITCHBOARD
1E

77.169

Figure 4-17.—Ship's service and emergency switchboard interconnection.

example, if lamp A is dark and lamps B and C are bright, phase A is grounded. In this case, the primary of the transformer on phase A is shunted by ground and receives no voltage.

BUS TIES

The connections between the ship's service and, the emergency generating units and their associated switchboards and the interconnections between the switchboard are illustrated in the schematic line diagram in figure 4-17. The a-c buses on the forward and after ship's service switchboards can be connected together, and the d-c buses on these switchboards can also be connected together. This arrangement enables one generating unit to supply power to both ship's service switchboards when the other unit is out of service, and also provides for parallel operations of the two ship's service generating units (1SG and 2SG). However, when operating SPLIT PLANT the generators are operated separately, each unit supplying power for its own section of the ship.

MAINTENANCE

The purpose of maintaining a power distribution system is to ensure that the generators, switchboards, and transfer equipment are ready for service at all times. Basic to the maintenance of this equipment are the procedures and means for keeping the equipment clean and dry, keeping electrical connections and mechanical fastenings tight, and inspecting or testing to determine the operating condition of the equipment.

GENERATORS

The main concern in generator maintenance is keeping the electrical insulation clean and dry and in good condition (high resistance). If generators are not kept clean, they will tend to overheat due to the presence of dust, dirt, and other foreign matter, such as particles of carbon, copper, and mica. Excessive operating temperatures will result in damage to the electrical insulation. The windings will eventually short circuit or ground out because the foreign matter is abrasive or conducting or forms a conducting paste (through absorption of moisture or oil). Generators can be cleaned with rags, vacuum cleaner, compressed air, or approved solvents. Wiping with a clean, lintfree, dry rag (such as cheesecloth) is effective for removing loose dust or particles from accessible parts. Grit, abrasive dust, and copper particles are removed from inaccessible parts by vacuuming or blowing with dry, clean compressed air. Vacuuming is preferred to blowing. Using compressed air is of little benefit unless the dust is removed from the generator. Approved cleaning solvents are to be used only where necessary to remove grease and pastelike substances that contain oil or carbon.

Portable electric lights (with guard) may be placed inside idle generators not provided with space heaters to keep the insulation dry. Only enough heat to keep the temperature inside the generator, about 5° to 10° above ambient temperature is required. Measuring insulation resistance of idle generators at sufficiently short intervals will help to detect moisture absorbed by the windings.

At least once a year and during each overhaul, each switchboard propulsion control cubicle, distribution panel, and motor controller should be deenergized for a complete inspection and cleaning of all bus work equipment. The inspection of deenergized equipment should not be limited to visual examination but should include grasping and shaking electrical connections and mechanical parts to be certain that all connections are tight and that mechanical parts are free to function. Be certain that no loose tools or other extraneous articles are left in or around switchboards and distribution panels.

Check the supports of bus work and be certain that the supports will prevent contact between bus bars of opposite polarity or contact between bus bars and grounded parts during periods of shock. Clean the bus work and the creepage surfaces of insulating materials, and be certain that creepage distances (across which leakage currents can flow) are ample. Check the condition of control wiring and replace if necessary.

Be certain that the ventilation of rheostats and resistors is not obstructed. Replace broken or burned out resistors. Temporary repairs can be made by bridging burned out sections when replacements are not available. Apply a light coat of petroleum to the face plate contacts of rheostats to reduce friction and wear. Be certain that no petrolatum is left in the spaces between the contact buttons as this may cause burning or arcing. Check all electrical connections for tightness and wiring for frayed or broken leads.

The pointer of each switchboard instrument should read zero when the instrument is disconnected from the circuit. The pointer may be brought to zero by external screwdriver adjustment. Caution: This should not be done unless proper authorization is given. Repairs to the switchboard instruments should be made only by the manufacturers, shore-repair activities, or tenders.

Be sertain that fuses are the right size; clips make firm contact with the fuses; lock-in devices (if provided) are properly fitted; and that all connections in the wiring to the fuses are tight.

SWITCHBOARDS

Switchboards and distribution panels should be deenergized after firing, if practicable, and thoroughly inspected for tightness of electrical connections and mechanical fastenings. Emergency switchboards should be tested regularly in accordance with the instructions furnished with the switchboard in order to check the operation of the automatic bus transfer equipment and the automatic starting of the emergency generator. This test should be made in connection with the weekly operating test of emergency generators.

Bus bars and insulating materials can be cleaned with a dry wiping cloth, or a vacuum cleaner. Be certain that the switchboard or distribution panel is completely dead and will remain so until the work is completed; avoid cleaning live parts because of the danger to personnel and equipment.

The insulated front panels of switchboards can be cleaned without deenergizing the switchboard. These panels can usually be cleaned by wiping with a dry cloth. However, a damp, soapy cloth can be used to remove grease and fingerprints. Then wipe the surface with a cloth dampened in clear water to remove all soap and dry with a clean, dry cloth. Cleaning cloths must be wrung out thoroughly so that no water runs down the panel. Clean a small section at a time and then wipe dry.

Control circuits should be checked to ensure circuit continuity and proper relay and contactor operation. Because of the numerous types of control circuits installed in naval ships, it is impracticable to set up any definite operating test procedures in this rate training manual. In general, certain control circuits, such as those for the starting of motors or motor-generator sets, or voltmeter switching circuits, are best tested by using the circuits as they are intended to operate under service conditions.

Protective circuits, such as overcurrent, reverse power, or reverse current circuits, usually cannot be tested by actual operation because of the danger involved to the equipment. These circuits should be visually checked, and, when possible, relays should be operated manually to be certain that the rest of the protective circuit performs its intended functions. Exercise extreme care not to disrupt vital power service or to damage electrical equipment.

BUS TRANSFER EQUIPMENT

Bus transfer equipment should be tested weekly. For manual bus transfer equipment, manually transfer a load from one power source to another and check the mechanical operation and mechanical interlocks. For automatic bus transfer equipment, check the operation by means of the control push-switches. The test should include operation initiated by cutting off power (opening a feeder circuit breaker) to ascertain if an automatic transfer occurs.

CHAPTER 5

TEST EQUIPMENT

As an IC Electrician, you will find it necessary to use a variety of test equipment to help troubleshoot and repair the newer, more sophisticated electrical/electronic gear aboardship. This chapter provides you with a useful and logical troubleshooting procedure, and describes the test equipment that you are likely to operate when troubleshooting and repairing the installed electrical/electronic gear.

TROUBLESHOOTING

Troubleshooting is the art of locating the problem. Like any art, it requires talent and training before it is developed into truly great work. Over the years IC Electricians have developed specific theories as to how to go about their art, and since they are passed on to you free of charge it will stand you well to use them.

The first step in logical troubleshooting is to recognize a normal condition; in other words, to determine that everything is working properly. For example, the second hand on our watch is going through 360 degrees in a clockwise direction every minute, the chances are pretty good that the second hand on your watch is working properly. If, however, you had never seen a watch before, you would have no idea that this was the proper method for the second hand to work and therefore would have no way of knowing that the hand was working properly. When you are dealing with a dead reckoning tracer or cyrocompass, the problem of recognition of normal conditions is far more complicated and you may need an explanation from a senior or from the manufacturer's technical manual. The point is you must have a fair comprehension of the normal condition of a piece of equipment before you can consider maintenance of it.

A second logical step in the art of troubleshooting is the ability to recognize that a malfunction is occurring, is about to occur, or has at some time past occurred. Then we assume that the equipment is not functioning normally, or that we have available information that indicates it will not function normally for much longer.

Picture again the watch, but this time the second hand is stopped. A malfunction has occurred at some previous time. It may be that someone has forgotten to wind the watch, but since you recognize that the normal condition is for the second hand to complete 360 degrees in 1 minute and since it is not moving, you are aware that a malfunction has occurred. If, however, when you looked at the watch you noted that the second hand was moving at a rate of but 10 degrees in a 1-minute period, you could safely assume that a malfunction was occurring at that time. The third situation would be in effect that you find the watch running at the proper rate but noted a grinding sound from somewhere in its interior. You could then assume with some reliability that a malfunction was about to occur in some future time. Again it must be emphasized that the criterion of step one remains true: you must be able to recognize a normal condition before you can determine that there is a malfunction.

Step three in logical troubleshooting falls right in place once you are sure of the malfunction's existence. Collect all available data regarding the malfunction in order to find the symptoms. Is the unit running at all? Is it within the normal temperature and pressure range? Has this malfunction occurred before? Is the malfunction occurring only during a specific set of circumstances? Is the unit noisy?—Out of calibration?—Over or under design limits? Don't overlook anything, as the smallest unit of information that you collect may in the final analysis be the solution to the problem.

Now that you have collected all of the symptoms of the malfunctions, the next step is to list, mentally or on paper, the possible causes of these symptoms. Many manufacturer's technical manuals list the "probable cause" in the corrective maintenance sections. It is often wise at this point to discuss the malfunction with another IC

Electrician. Giving him the symptoms may result in his coming up with several causes that were not apparent to you.

Armed with a complete set of symptoms and with the probable causes of these symptoms, the troubleshooter now begins the painstaking checks which will ultimately lead to isolation of the malfunction. To sectionalize the trouble means to track it down into one specific area of a piece of equipment. This may be done by going over the energizing procedure slowly and determining when the trouble first appears. It may be done through the use of a troubleshooter's chart listed in the manufacturer's technical manual. It also can easily be performed through the use of the probable causes that you have listed.

Once it has been determined which section of a system is malfunctioning, it is usually but a matter of time before the defective component or components are isolated and repairs can be made. During this final step of troubleshooting it is most important that you, the Interior Communications Electrician, use every method of isolation. An open resistor can be determined through the use of a meter, but time is wasted if you do not note that the component is discolored when you originally open the chassis for inspection. It is imperative in troubleshooting that the IC Electrician give full attention—look, listen, smell, and feel—to ensure good, quick, trouble isolation.

PRECAUTIONS

Basic electrical indicating instruments receive extensive coverage in Basic Electricity, NavPers 10086 (Revised) and in Basic Electronics, NavPers 10087 (Revised) and all that is needed here is a reminder of certain specific precautions which are applicable to them and to all test equipment. The delicate mechanisms of most test equipment require that you take pains to avoid rough handling and the possibility of moisture and dust or fine magnetic particles entering the case. Other factors which have led to the ruining of certain pieces of equipment are the subjection of the unit to an input signal of a magnitude greater than the range which is selected on the input scale, use of the instrument in close proximity of strong magnetic fields, and subjecting the meter movement to high potential sources while attempting to calibrate or service it. When all is taken into account, you should understand the specific piece of equipment that you are using and the circuit upon which you are using it.

MULTIMETERS

Multimeters combine a voltmeter, ammeter, and ohmmeter in one unit and may be classified as either the electronic and nonelectronic type. A discussion of a representative unit of each type follows.

MULTIMETER AN/PSM-4(SERIES)

Multimeter AN/PSM-4A (fig. 5-1) is a portable, nonelectronic volt-ohm-milliammeter. It is designed to measure direct current (up to 10 amperes), resistance (up to 30 megohms), d-c voltage (up to 5000 volts), a-c voltage (up to 1000 volts rms) or output voltage (up to 500 volts rms). The complete unit includes test probes which may be used with their prod tips, or the tips can be fitted with alligator clips or with a telephone plug to simplify contact arrangements and connections. A high voltage probe is also included, which makes it possible to read voltages up to 5000 VDC. This probe contains a warning light to indicate the presence of high voltage.

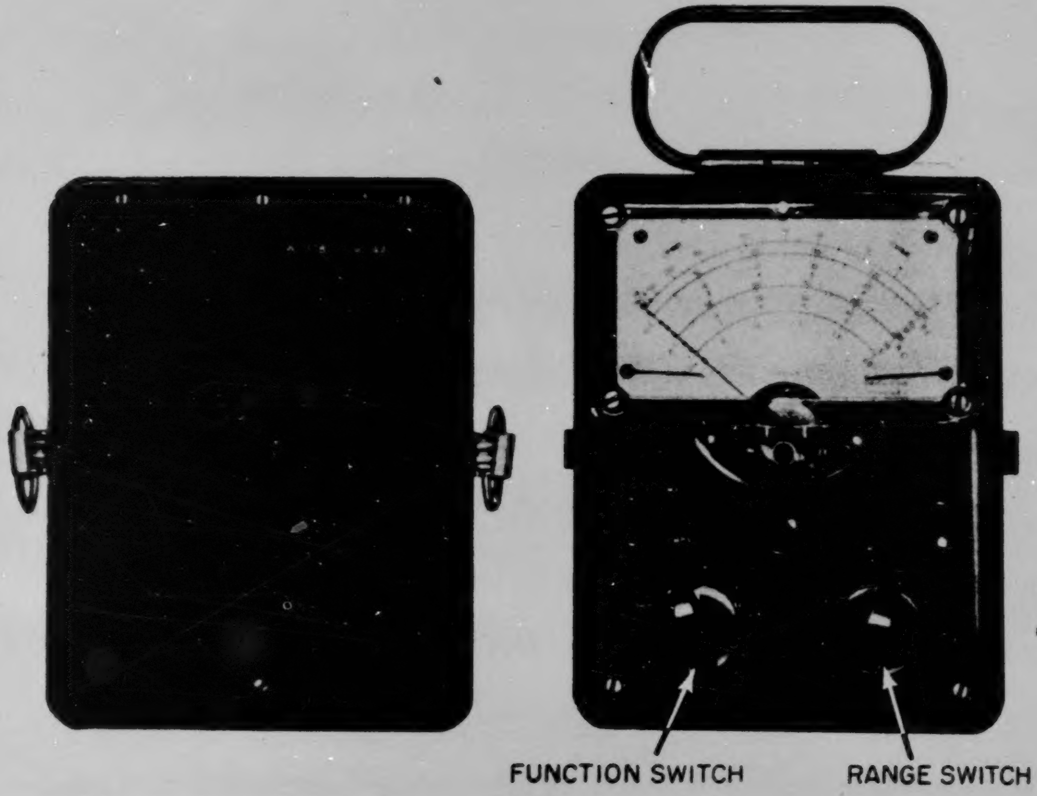
The Multimeter AN/PSM-4 series comprises the 4A through 4E meters. Except for minor circuit changes to the basic meter, they are identical. The instrument part of each multimeter contains circuits for measuring current, resistance, or voltage separately.

D-C Voltmeter Circuits

The block diagram of the circuit in Multimeter AN/PSM-4A which is used for measuring d-c voltages is shown in figure 5-2. The circuit is selected with function switch S101, in either its DIRECT or REVERSE DCV position (fig. 5-1). For voltages up through 500 volts, a range is selected with range switch S-102 (only one position shown in figure 5-2). For the 1000-volt range, the read test lead connects into the special 1000 VDC jack (fig. 5-1), and the range switch is not in the circuit. For the 5000-volt range the high voltage probe (not shown) connects the special 5000 VDC jack, and places its resistance in series with the meter movement. For any range, the total resistance in series with the meter movement will regulate the meter current to provide a proportional current to indicate the amount of voltage in the circuit.

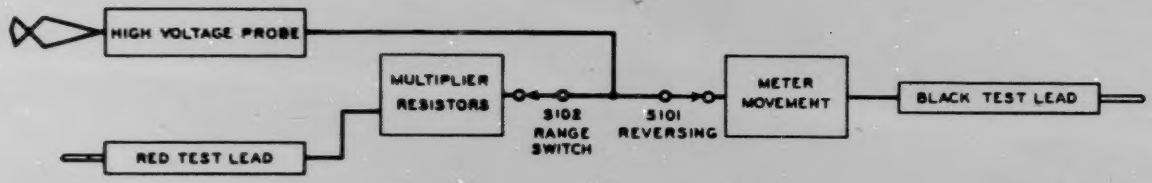
A-C and Output Voltage Circuits

The circuits which measure a-c and output voltages (fig. 5-3), are selected with the ACV and


FUNCTION SWITCH
RANGE SWITCH

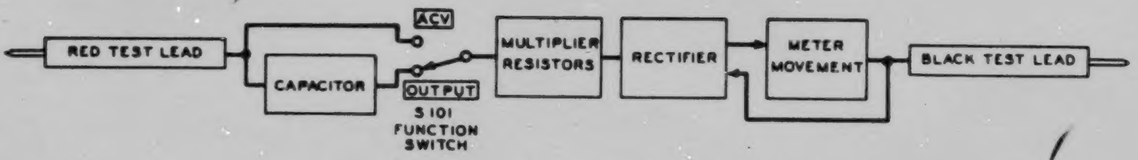
4.133

Figure 5-1. — Multimeter AN/PSM-4A.


HIGH VOLTAGE PROBE
MULTIPLIER RESISTORS
S102 RANGE SWITCH
S101 REVERSING
METER MOVEMENT
BLACK TEST LEAD
RED TEST LEAD

1.311

Figure 5-2. — Functional block diagram of d-c voltage circuits.



1.312

Figure 5-3.—Functional block diagram of a-c and output voltage circuits.

OUTPUT positions of function switch S-101. For voltages up through 500 volts, a range is selected with range switch S-102. For the 1000-volt range, the red test lead connects the special 1000 VAC jack, and the range switch, S-102, is not in the circuit. The a-c voltage impressed across the circuit between the red and black test leads tries to send current through the resistance of the circuit in both directions, but the rectifier allows only one direction of current flow through the meter movement. The meter is calibrated to indicate the RMS value of the a-c voltage applied to the instrument circuit.

Direct Current Circuits

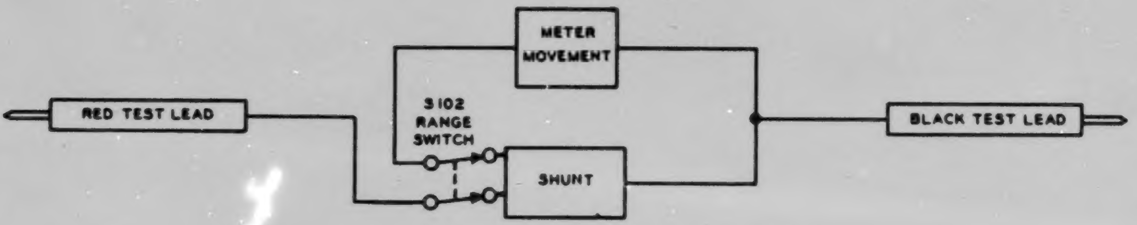
The circuit which measures direct current is selected with the d-c μA MA AMPS position of function switch S-101 (fig. 5-1). For currents up to 1000 milliamperes, the range is selected with range switch S-102 (fig. 5-4). For the 10 ampere range, the red test lead connects the special 10 AMPS jack, and range switch S-102 is not in the circuit. Each range provides a parallel shunt resistance for the meter movement, and the circuit current divides between these two parallel paths. The proportional part which passes through the meter movement indicates the total circuit current.

Ohmmeter Circuits

The ohmmeter circuit (fig. 5-5) and its ranges are selected with function switch S-101. The ranges are Rx1, Rx10, Rx100, Rx1000, and Rx10000. An internal battery furnishes the power for all resistance measurements. For each range, the circuit is arranged so the meter will indicate zero ohms, and full scale deflection when the red test lead and the black test lead are shorted together. When you connect a resistance between the test leads, this resistance will be in series with the instrument circuit, and less current will flow through the meter movement. The amount of reduced meter deflection indicates how much resistance is between the test leads.

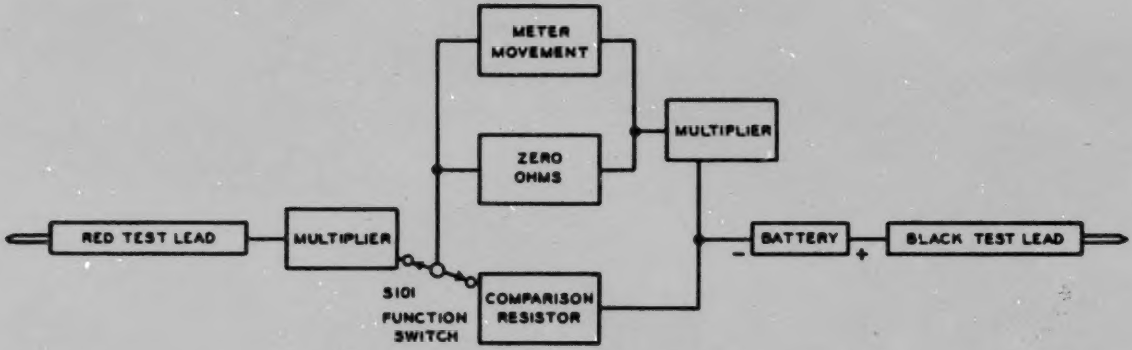
Function Switch S-101

Function switch S-101, (fig. 5-1) located in the lower left-hand corner of the front panel, selects the type of circuit for which the instrument is connected. There are two positions for d-c volts: DIRECT and REVERSE. The normal position is DIRECT. When using the meter to make a d-c voltage measurement and a connection is made which causes the meter to read backwards (deflection of the pointer to the left), set switch S-101 to REVERSE and the pointer will be deflected up-scale. To read alternating current



1.313

Figure 5-4.—Functional block diagram of d-c circuits.



1.314

Figure 5-5. — Functional block diagram of ohmmeter circuits.

voltages, set switch S-101 to the ACV position. A rectifier within the instrument rectifies the a-c voltage to an equivalent d-c value, and the meter indicates the RMS value of the applied voltage. To read the a-c portion of mixed a-c and d-c voltages, set switch S-101 at OUTPUT. Set switch S-101 at d-c μ A MA AMPS to read direct current. As mentioned previously, switch S-101 also serves as a range switch for resistance measurements.

Range Switch S-102

This eight-position range switch located in the lower right corner of the front panel permits the selection of voltage and current ranges. The full scale value for each range switch position is marked on the front panel.

Zero Ohms Controls

The ZERO OHMS control is located near the center of the front panel. Each time the function switch S-101 is placed in a position to read resistance, short the test leads together and rotate the ZERO OHMS control knob to make the pointer read full scale, or zero ohms. If you cannot bring the pointer to full scale, replace the battery in the rear of the case.

Test Leads and Test Jacks

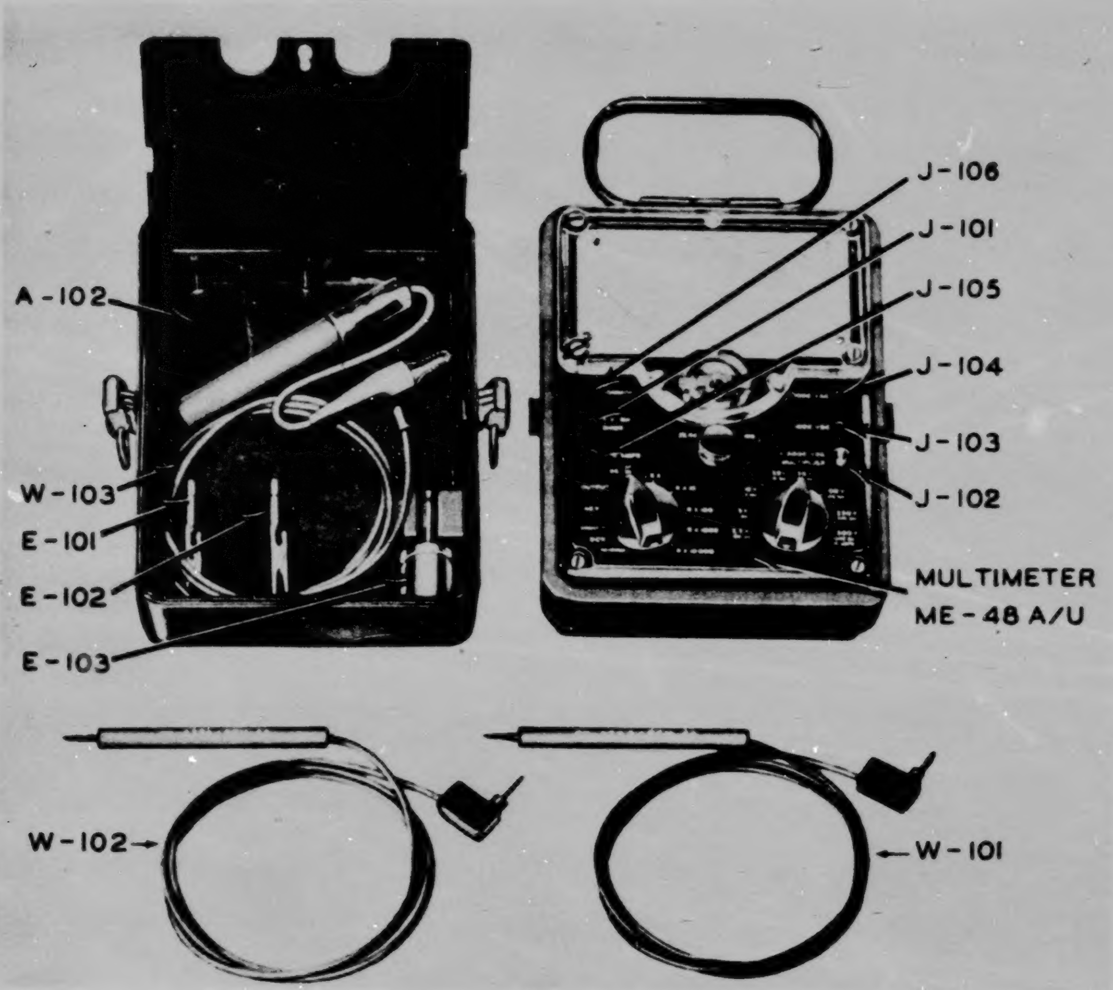
There are two test leads, W-101 and W-102, (fig. 5-6) which are needed for all measurements except those which require the 5000 VDC range. Test lead W-101 is red and test lead W-102 is black. Unless other wise specified, connect black test lead W-102 in the COMMON jack, J106, and connect the red test lead W-101 in the + V MA OHMS jack, J101. For the 1000 VDC range, place red test lead W-101 in the 1000 VDC jack, J-103. For the 1000 VAC range, place red test lead W-101 in the 1000 VAC jack, J104. Use the red test lead to contact the positive side of the source for d-c measurements and the black test lead to contact the negative side. For the 5000 VDC range, use black test lead, W-102 in the COMMON jack, J-106, and use the high voltage test lead, W-103, screwed on over recessed post J-102, +5000 VDC MULTIPLIER. For the 10 ampere range, place red test lead, W101, in the special 10 AMPS jack, J105.

Accessories E-101, E-102, and E-103

There are two alligator clips, E-101 and E-102, which the operator may use to screw on over the end of test leads W-101 and W-102. This is for the convenience of the operator. There is a telephone plug, E-103, which may be used to connect both the test leads, W-101 and W-102, to contacts within a two-contact telephone jack. This permits easier connection to the jack contacts for any electrical measurement because the operator can make the measurement directly through an equipment panel without opening the case of the equipment. The red test lead W-101, connected in the red insulated jack (not shown) on the rear of telephone plug E-103, contacts the tip of the plug. The black test lead, W-102, connected in the black insulated jack (not shown) on the rear of the telephone plug, E-103, contacts the sleeve of the plug.

ELECTRONIC MULTIMETER AN/USM-116

At times accuracy is a major consideration in the art of troubleshooting. When working with the underwater log or the gyrocompass circuits,



4.133(ME-48A/U)

Figure 5-6.—Control, jacks, leads, and accessories.

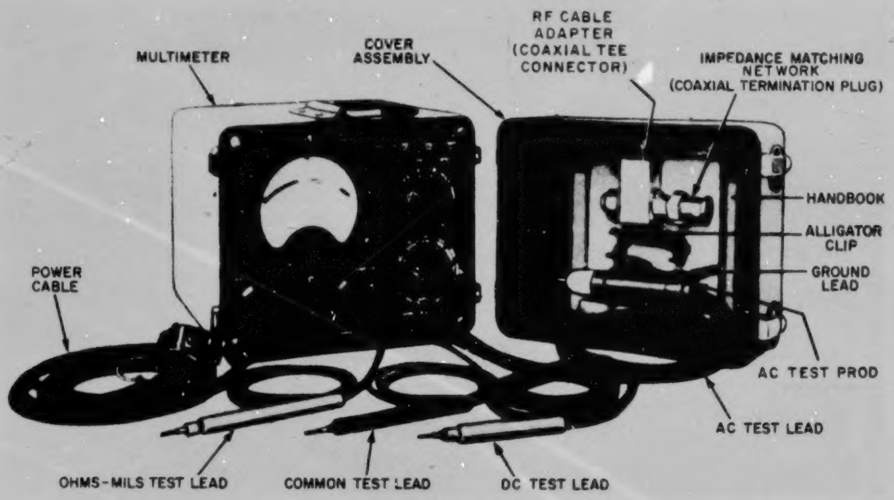
the IC Electrician must often adjust to within a few millivolts or perhaps a milliampere. To enable him to maintain close tolerances, the Navy has developed a series of portable electronic multimeters of which the AN/USM-116 is a representative model. With a high degree of accuracy, this instrument measures voltage, current, and resistance values, using a relatively high input impedance to prevent loading the circuit under test.

The values listed below are within the range of the AN/USM-116:

A-c volts	0.01 to 300 rms
D-c volts	0.02 to 1000
Direct current	20 microamps to 1000 milliamps
Resistance	0.2 ohms to 1000 megohms

The unit pictured in figure 5-7A requires a 115-volt a-c power source, and along with its 8-foot power cord contains 4 permanently connected test leads.

Two unshielded leads or probes are used to measure both resistance and current. A third, red in color, is used in conjunction with the common of the former two in the measurement of d-c voltage. This probe contains a 36-megohm resistor to eliminate the capacitance caused by interaction with its shield. The fourth lead, used for a-c voltage, is recognizable by the permanent

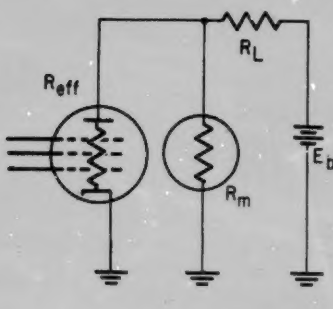

MULTIMETER
COVER ASSEMBLY
RF CABLE ADAPTER (COAXIAL TEE CONNECTOR)
IMPEDANCE MATCHING NETWORK (COAXIAL TERMINATION PLUG)
HANDBOOK
ALLIGATOR CLIP
GROUND LEAD
POWER CABLE
AC TEST PROD
AC TEST LEAD
OHMS-MILS TEST LEAD
COMMON TEST LEAD
DC TEST LEAD

4.133

Figure 5-7A. —Multimeter AN/USM 116.

attachment of an RF type probe for use on high-frequency circuits. When high frequency is measured, a ground attachment is employed and connects directly to the a-c probe. The a-c probe also contains a diode circuit as the meter circuit is designed for d-c measurement only.

The USM 116 has four operating controls. The Function Switch selects the desired parameter to be measured, that is current, resistance, a-c voltage or d-c voltage. The Range Switch preselects the scale of the meter for the chosen parameter. A Zero Adjust permits the accurate setting of all scales through the use of two single-mounted potentiometers. The Ohms Adjust is used to precalibrate the meter for any of the ohmmeter functions. The Function Switch is also used as an on-off switch with a 15-minute warmup time being recommended for greater meter accuracy.


R_L
R_{eff}
E_{bb}
R_m

189.52

Figure 5-7B. —Loading effect created by meter resistance.

The meter face contains a zero adjustment screw which can, by mechanical means, preset the meter to the true zero. This adjustment is directly below the face glass, and should be made prior to warmup. If it is necessary to re-adjust this control, it should be done with all probes disconnected and the function switch in the mils position.

VACUUM TUBE VOLTMETERS

The a-c rectifier type of voltmeter has several disadvantages that make it practically useless for measuring voltages in high impedance circuits. For example, suppose that the plate voltage of a pentode amplifier is to be measured. (See fig. 5-7B.) When the meter is connected between the plate and cathode of the electron tube, the meter resistance R_m, is placed in parallel with the effective plate resistance R_{eff}, thereby lowering the effective plate resistance. The effective plate resistance is in series with the plate load resistor, R_L, and this series circuit appears across the supply voltage, E_{bb} as a voltage divider. Since the overall resistance is lowered, it follows that current through R_L will increase, the voltage drop across R_L will also increase, and the voltage drop across R_{eff} will decrease. The result is an incorrect indication of plate voltage, the effect of connecting this meter in the circuit is called loading effect.

A meter having a sensitivity of 20,000 ohms per volt and a 250-volt maximum scale reading would introduce an error of about 1 percent. The lower the sensitivity of the meter, the greater the error. However, in circuits where very high impedances are encountered, such as in grid circuits of electron tubes, even a meter of 20,000 ohms per volt sensitivity would impose too much of a load on the circuit.

Another disadvantage of the a-c rectifier type of voltmeter is the shunting effect at high frequencies of the relatively large capacitance of the rectifier. This shunting effect may be eliminated by replacing the usual metallic oxide rectifier with a diode electron tube; the output of the diode is applied to the grid of an amplifier in which the plate circuit contains the d-c meter. Such a device is called an electron tube voltmeter or a vacuum tube voltmeter, usually abbreviated VTVM. Voltages at frequencies up to 500 megacycles, and sometimes even higher, can be measured accurately with this type of meter. The frequency limitation is determined by the model of VTVM.

The input impedance of a VTVM is large, and therefore the current drawn from the circuit whose voltage is being measured is small and in most cases negligible. The main reason for using a vacuum tube voltmeter is to overcome the loading effect by taking advantage of the VTVM's extremely high input impedance. A VTVM that is used extensively for electronics maintenance is contained in the AN/USM 116 multimeter described earlier.

The VTVM measures d-c voltages from 0.02 volt to 1,000 volts and a-c voltages from 0.01 volt to 300 volts rms at frequencies from 30 cps to 1 mc. With an adapter it can measure RF voltages.

TUBE TESTERS

Although rigid controls reduce tube failures considerably, tube testers provide some means of determining the condition of tubes that have been in use for some time, as well as the condition of new tubes that are to be placed in equipment. In general, tube testers do not completely indicate tube performance because they present a fixed impedance to the tube grid and plate which may or may not be that of the equipment in which the tube is to operate. Also, the tester takes no account of the interelectrode capacity of the tube. Military specifications allow a wide deviation of interelectrode capacity which makes an accurate prediction of tube performance with a tube tester difficult. The range of operating frequency affects performance also.

It is impracticable to design a complete testing instrument that will evaluate the performance of any tube in any circuit in which it is being used. A tube may test low on the tester and yet work perfectly well in the circuit or, on the other hand, it may check good in the tester and not function in the equipment. As a rule, therefore, only dead, shorted, or extremely weak tubes should be discarded purely on the basis of a tube tester check.

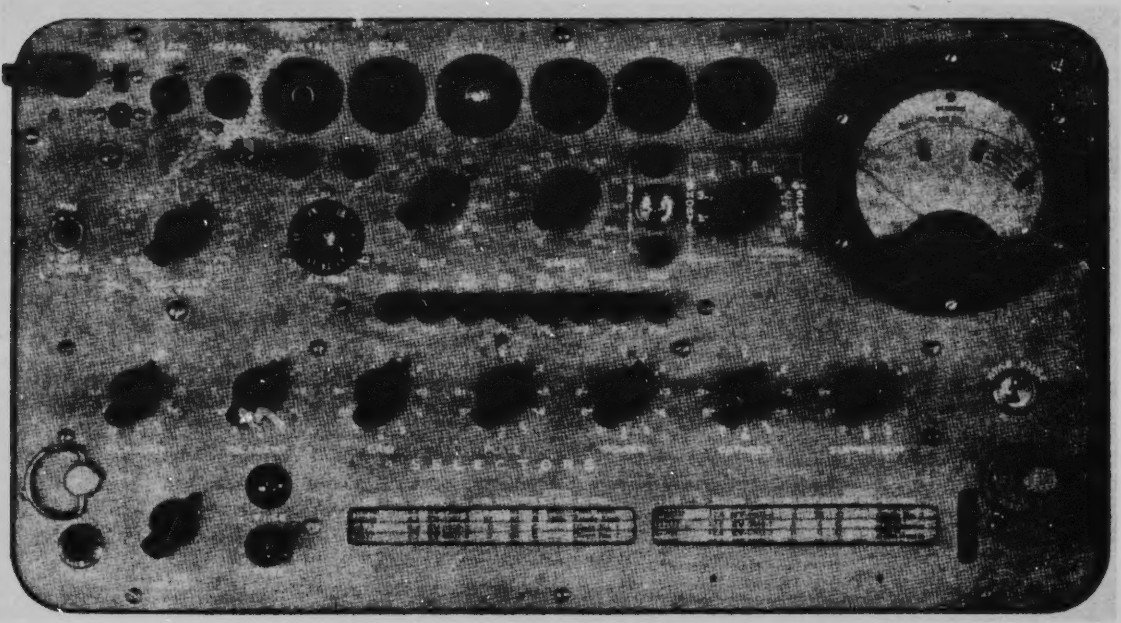
The two principal types of tube testers are the emission tester and the mutual conductance or transconductance tester. An emission tester measures the ability of an electron tube to emit electrons from its cathode. A mutual conductance tester indicates the ability of the grid voltage to control the plate current. Tube testers are also capable of detecting short circuits and leakage between tube elements and showing the presence of too much gas in electron tubes.

ELECTRON TUBE TEST SET MODEL TV-10A/U

Model TV-10A/U is a typical mutual conductance tube tester. Mutual conductance is defined as the ratio of the change in plate current to the change in grid potential producing it, under the condition of constant plate voltage. Mutual conductance is expressed in micromhos (symbol Gm) and the condition of the tube is indicated on the meter scale directly in micromhos.

Test Set Panel

The TV-10A/U panel is shown in figure 5-8. The tube sockets are grouped along the top edge and in the upper left-hand section of the panel as follows: Along the top edge reading from the left are test sockets for SUBMINIATURE tubes; 7 pin MINIATURE tubes; 9 pin NOVAL base miniature tubes; LOCTAL and OCTAL tubes; a combination large and small radius socket for standard 7 pin tubes, which also provides a pilot lamp test receptacle; and sockets for standard 6, 5, and 4 pin tubes. An acorn tube socket designed to accommodate all tubes of this type now in use is located at the right of the filament voltage switch.



20.346(5)

Figure 5-8. — Tube tester panel.

The power switch controls the a-c power input to the tester. The pilot lamp indicates whether power is on or off. The cartridge fuse, rated at 1 ampere, protects the a-c line. Overloading the tester or a tube under test is indicated by the fuse lamp. The line adjust control enables the test set operator to vary the input voltage to a power transformer in order to standardize the voltage for the test circuits. In this way, proper test potentials are maintained at all tube elements under varying conditions of line voltage.

The test set operator consults the roll chart for the proper settings of the switches, controls, and selectors on the panel. Column headings on the panel above the index window make it easy to refer to the tube test data on the roll chart.

The filament voltage switch selects the proper filament or heater voltages from 0.6 volts through 117 volts, alternating current in 18 steps. Another position on this switch, marked BLST provides for testing ballast tubes. An OFF position is also provided.

The bias control is used to adjust the bias voltage to the proper value for the tube under test. The bias fuse lamp protects this control.

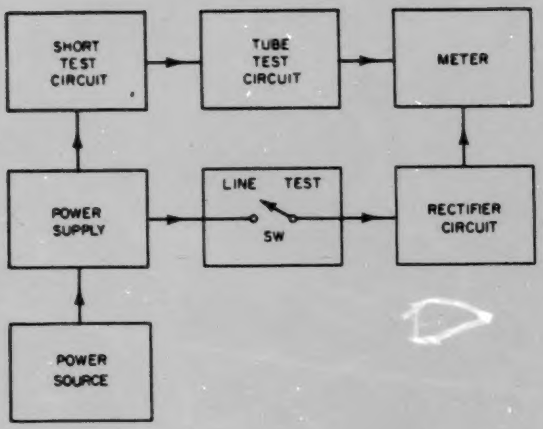
The shunt control is a potentiometer that controls the sensitivity of the meter circuit to the proper level for testing rectifier and diode tubes.

The shorts-micromhos switch selects the proper range of mutual conductance in micromhos for the tube under test, as indicated on the roll chart. The letters (A, B, C, D, and E) at the five right-hand positions of this switch indicate the scale for reading the meter. The switch also has five left-hand positions for testing shorts. The neon lamps glows to indicate a short circuit.

Pushbutton switches located in the center of the panel actuate the final circuit selector switches for testing as follows:

P1: Line adjust.
P2: Diodes (tubes having no grid), such as 6H6.
P3: Mutual conductance of amplifier tubes only; NEVER RECTIFIER TUBES.
P4 and P5: Gas.
P6: Cold cathode rectifiers, such as OZ4.
P7: Rectifiers, such as 5Y3, 6X4, 83, etc.
P8: Reversing polarity of voltage applied to the meter (certain types of tubes).

Proper switching of the internal circuits to apply correct test voltages to the various pins of the tube under test is provided by the selectors


SHORT TEST CIRCUIT
TUBE TEST CIRCUIT
METER
POWER SUPPLY
LINE
TEST
SW
RECTIFIER CIRCUIT
POWER SOURCE

140.142

Figure 5-9.—Block diagram, tube tester.

on the panel (two filaments, one grid, one plate, once screen, one cathode, and one suppressor).

Fundamentals of Operation

The various circuits of the test set are related as shown by the block diagram of figure 5-9. The source of power is 105 to 125 VAC at any frequency between 50 and 1600 hertz. The power supply has a transformer consisting of the primary winding and seven secondary windings. One of the secondary windings is tapped at several points to supply the filament voltage for all types of tubes. Other secondary windings supply filament and plate voltages to rectifier tubes in the tester. The d-c output of these tubes is used for the electrode supply voltages for tubes under test.

The line test adjusts the meter indication to the line voltage. Normally, with the meter pointer over the line test mark, the rms voltage across the transformer primary will be 93 volts.

In figure 5-10A, the shorts test circuit detects short circuits and leakage between tube elements.

The rectifier circuit (fig. 5-10B) is used to test rectifier tubes and diode tubes, which require an emission test only. In this test, the shorts-micromhos switch is set at position A, which connects a shunt potentiometer into the rectifier circuit. In positions B, C, D, and E, fixed shunt resistors are connected across the meter to provide the proper signal voltage for the Gm scale that is selected.

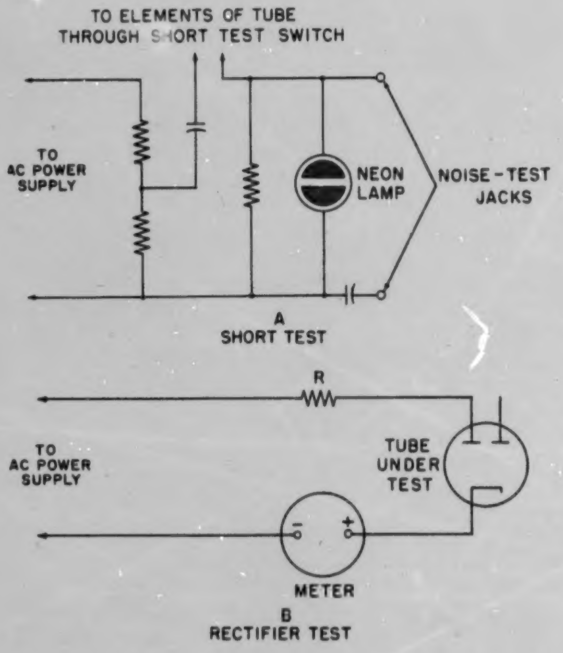

TO ELEMENTS OF TUBE THROUGH SHORT TEST SWITCH
TO AC POWER SUPPLY
NEON LAMP
NOISE-TEST JACKS
A
SHORT TEST
R
TO AC POWER SUPPLY
TUBE UNDER TEST
METER
B
RECTIFIER TEST

Figure 5-10.—Simplified short- and rectifier-test circuits. 20.347

The tube test circuit applies the proper a-c grid and plate voltages to the tube under test. An a-c voltage is applied in series with the grid bias to swing the grid in positive and negative directions from the d-c bias value, thereby producing the grid voltage required for a dynamic test. The plate voltage is furnished by

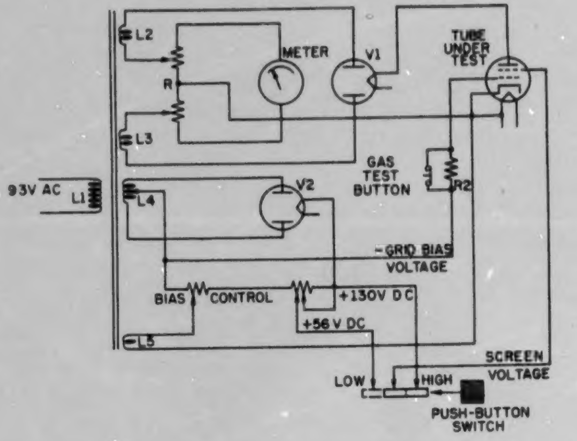

L2
METER
V1
TUBE UNDER TEST
R
L3
GAS TEST BUTTON
R2
93V AC
L1
L4
V2
-GRID BIAS VOLTAGE
BIAS
CONTROL
+130V DC
+56V DC
L5
SCREEN VOLTAGE
LOW
HIGH
PUSH-BUTTON SWITCH

Figure 5-11.—Simplified mutual-conductance test circuit. 20.348

another full-wave rectifier. The meter is connected in the negative return of this circuit and indicates the change in plate current (fig. 5-11).

As mentioned earlier, the test set can show whether or not there is excessive gas in a tube. In the gas test, normal filament, grid, and plate voltages are applied to the tube to cause a definite value of plate current to flow, which shows on the meter. Pressing the gas test button inserts a resistance in series with the grid circuit. If grid current is flowing because of the presence of gas in the tube, a voltage drop will take place across the series resistor. This voltage drop will reduce the grid bias, and the plate current will rise. The rise will be shown by an increase in meter reading. A slight increase in meter reading (no more than one scale division) is permissible.

Testing Practices and Precautions

Be sure the tester is connected to a 105- to 125-volt a-c power source, not a d-c power supply line. The frequency of the source can be 50 to 1600 hertz.

Do not insert a tube in any test socket without first adjusting the controls properly. For tubes having top grid connections, top plate connections, or both, use the test leads supplied with the tester. Dangerous voltages are present at the top cap connections for certain tubes when test pushbuttons are depressed. Be sure to remove your hands from the test leads before pressing the pushbuttons. This lead is kept in the case of the test set.

Check all tubes for shorted elements first. If a tube is shorted, do not make any other tests. When testing rectifier tubes, do not depress the red pushbutton P3; it is used in testing the mutual conductance of amplifier tubes only.

Turn the power switch off immediately if the fuse lamp flashes brightly. This lamp is an overload indicator that will burn out, of course, under prolonged or excessive overload.

Turn the shorts-micromhos switch to position No. 5 immediately if the bias fuse lamp glows. This lamp shows an accidental overload due to a shorted tube. An excessive or prolonged overload will burn out the lamp.

Furthermore, it is NOT advisable to replace a large number of tubes especially in high frequency circuits without checking their effect on the circuit, one tube at a time. In any complicated circuit it is bad practice to arbitrarily replace a large number of tubes. It is better to replace them either tube by tube or in small groups. Be sure to replace each tube with an identical replacement.

Maintenance

It may become necessary to replace fuses, pilot lamps, rectifier tubes, or the neon short indicator lamp, in the tester from time to time. However, the proper use of the tube chart and instruction book will prevent accidental damage to tube tester components. The rectifier tubes in the tester should operate for a much longer time than the same type of tube used in continuous service. Failure of the type 83 rectifier tube can be detected without opening the case of the test set. This tube supplies plate voltage, and its failure is indicated if the pointer of the meter moves sharply off scale to the right when the red pushbutton P3 is pressed (with no tube in the test sockets, but the controls set for tube test).

The type 5Y3 rectifier tube furnishes d-c screen and bias voltages for the tube under test. The instruction book will show how these voltages can be checked without removing the panel from the case.

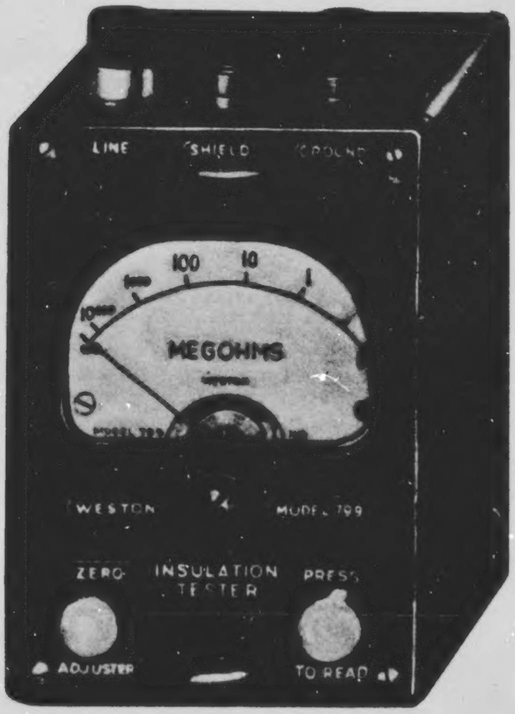
MEGGERS

Meggers (megohmmeters) are used primarily to test insulation resistance. A megger employing a 500-volt d-c generator is described in Basic Electricity, NavPers 10086 (Rev.). Another type employing electronic circuitry is the CV-60089.

MEGOHMMETER, TYPE CV-60089

Electron tube megohmmeter, Navy type CV-60089 (fig. 5-12) is recommended for testing IC circuits and components that must be tested at a lower potential than 500 volts. Supplied with the tester are three test leads, and a leather carrying strap. The tester, test leads, and carrying strap are enclosed in a heavy oak case.

The rheostat marked ZERO ADJUSTER controls the plate and grid potentials of the amplifier tube. This rheostat is used to adjust the pointer to the zero or top mark division with the GROUND and LINE terminals short-circuited. The right-hand button marked PRESS TO READ is depressed whenever a reading is desired. This closes the filament circuit to the amplifier tube. There is no drain on the internal batteries unless this button is depressed.



1.55
Figure 5-12.—Megohmmeter, Navy Type CV-60089.

For normal operation, the LINE and GROUND terminals are used. The LINE binding post is insulated with polystyrene fittings and is guard-ringed against leakage current. The guard ring on this binding post connects to the center post marked SHIELD. Where surface leakage influences readings, such as in cable testing, a guard ring or a leakage shield should be applied to the surface of the insulation and connected to the SHIELD terminal.

To operate, connect one test lead to the ground terminal and one test lead to the line terminal. Short-circuit the clipped ends of the leads and depress the PRESS TO READ button. The pointer should deflect to the ZERO position. If adjustment is necessary, remove the ZERO ADJUSTER cap and rotate the adjuster screw bringing the pointer to the ZERO position. Replace the zero adjuster cap nut and connect the leads across the unknown resistance. Depress the PRESS TO READ button and note the resistance reading.

When circuits or components under test contain a large electrical capacity, the PRESS TO READ button must be depressed for a sufficient time to allow the capacitor (fig. 5-13) to charge before a steady reading is obtained. The test voltage applied by the megohmmeter to the unknown resistance is approximately .50 volts when measuring resistances of approximately 10 megohms. The voltage is slightly greater than this when measuring higher resistances.

Maintenance

After considerable use, the test leads may become worn or frayed, usually where they enter the hard rubber sleeves of the forked terminal. When this occurs, the sleeve should be unscrewed and the lead cut off beyond the worn spot and resoldered to the terminal.

Batteries for supplying voltage for the operation of the CV-60089 megohmmeter are contained in the bottom of the bakelite panel. These batteries are subject to deterioration either from use or from age. When the meter pointer cannot be brought to full scale with the test prods shorted and the ZERO ADJUSTER rheostat at maximum right-hand position, the batteries should be replaced.

The tube does not normally need replacing unless mechanically damaged. Never replace the tube unless all other component parts are in good working order.

If during an actual resistance testing operation, with the PRESS TO READ button depressed, the instrument pointer fluctuates due to an intermittent contact, remove the panel and clean the switch contacts with a piece of crocus cloth.

TACHOMETERS

A tachometer is an instrument which shows the rate at which a shaft is turning. Tachometer indicate in revolutions per minute (rpm) the turning rate of motors, generators, and other rotating machines. Though tachometers are installed on Navy machinery, such as ship's service generators and main engines, an IC Electrician must often determine the speed of a rotating machine that is not equipped with a tachometer. In this case, he uses a portable tachometer.

Portable hand tachometers measure speed by direct contact with the shaft of the measured unit. Each hand tachometer (fig. 5-14) comes with an assortment of hard rubber tips, one end of which

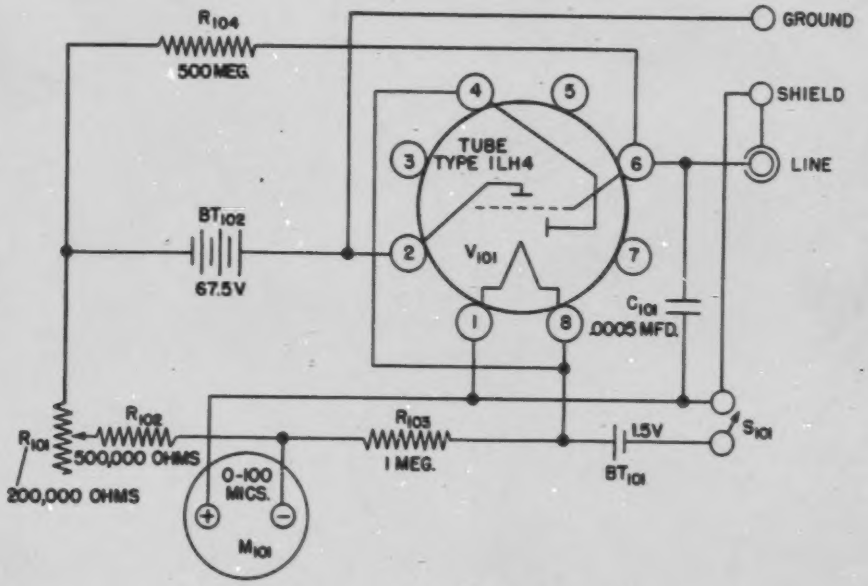


Figure 5-13. —Megohmmeter wiring diagram.

140.143

is inserted in the instrument the other applied to the rotating shaft.

Portable tachometers are for use only during testing and should not be used continuously. The tachometer shaft must be aligned to the center of the shaft of the unit under test; and offcenter position will yield an incorrect reading. Additionally you should ensure that the design limit of the tachometer is not exceeded.

The common types of tachometers are the centrifugal and chronometric.

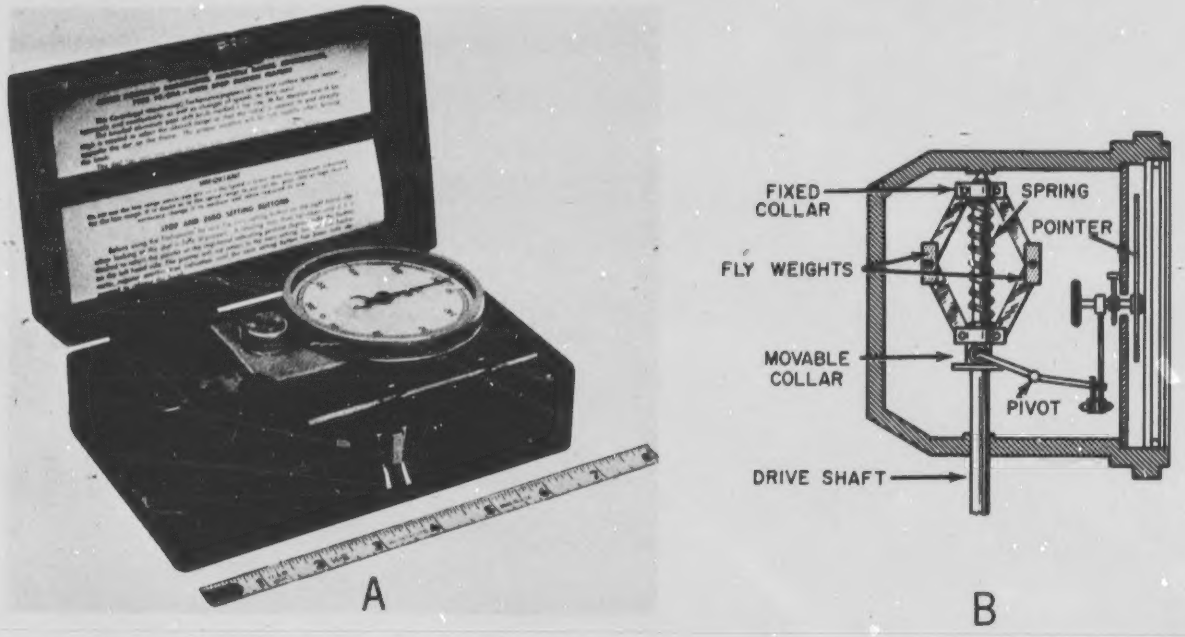
In the centrifugal type, (fig. 5-14B) centrifugal force acts upon weights or flyballs which are connected by links to upper and lower collars. The upper collar is affixed to a drive shaft while the lower is free to move up and down the shaft. A spring, which fits over the shaft, connects the upper and lower collars. As the drive shaft begins to rotate, the flyballs (or weights) rotate with it.

Centrifugal force tends to pull the flyballs away from the center, thus the lower collar rises and compresses the spring. The lower collar is attached to a pointer and its upward motion, restricted by the spring tension, results in an increase in the indication on the dial face. The unit when properly used indicates correct shaft speed as long as it is in contact with the machine shaft under test.

The centrifugal tachometer may be either portable (single and multiple range) or permanently mounted. The portable multi-range tachometer has three ranges: low (50 to 500 rpm), medium (500 to 5,000 rpm), and high (5,000 to 50,000 rpm).

Normally, permanently mounted centrifugal tachometers operate off the governor or speed limiting assembly. The tachometer continuously records the actual rotational speed of the machinery shaft.

The shaft, portable/CHRONOMETRIC tachometer, shown in figure 5-15A is a comination watch and revolution counter. It measures the average number of revolutions per minute of a motor shaft, pump shaft, etc. The mechanism of this tachometer is such that its outer drive shaft runs free when applied to a rotating shaft, until a starting button is depressed to start the timing element. Note the starting button beneath the index finger in figure 5-15B. The chronometric tachometer retains readings on its dial after its drive shaft has been disengaged from a rotating shaft, until the pointers are returned to zero by the reset button (usually the starting button). The range of a chronometric tachometer is



61.17X:2.66X

Figure 5-14.—Centrifugal tachometer.

usually from 0 to 10,000 rpm, and from 0 to 3,000 feet per minute (fpm).

Each portable centrifugal or chronometric tachometer is supplied with a small rubber covered wheel and a number of hard rubber tips. The appropriate tip or wheel is fitted on the end of the tachometer drive shaft, and held against the shaft to be measured. Portable tachometers of the centrifugal or chronometric type are used for intermittent readings only, and are not used for continuous operations.

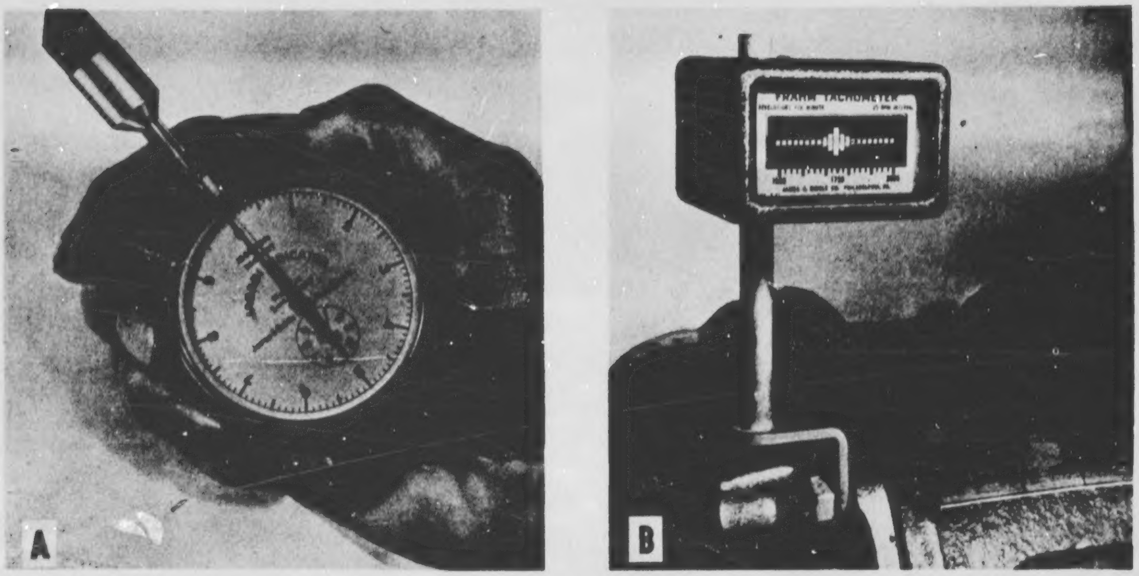
The RESONANT REED tachometer, illustrated in figure 5-15B is particularly useful for measuring high rotational speeds such as those that occur in urbines and generators. This type of tachometer is particularly suitable where it is practically impossible to reach the moving ends of the machinery shafts. This instrument gives continuous readings and is capable of making very rapid, instantaneous adjustments to rotational speed.

Resonance is the quality of an elastic body which causes it to vibrate vigorously when subjected to small, rhythmic impulses at a rate equal to its natural frequency, or nearly so. In a resonant reed tachometer, resonance provides a simple but accurate means for measuring speed and rate of vibration.

A resonant reed tachometer consists of a set of consecutively tuned steel reeds mounted in a case with a scale to indicate rpm of the shaft and vibrations per minute (vpm) of the reeds. This tachometer has not pointer—only a set of accurately tuned reeds—and it operates without direct contact with a moving part under test. It has no gears or couplings, and it requires no oiling and practically no maintenance.

STROBOSCOPIC TACHOMETER

The stroboscope is an instrument that permits rotating or reciprocating objects to be viewed intermittently and produces the optical effect of slowing down or stopping motion. For example, electric fan blades revolving at 1800 rpm will apparently be stationary if viewed under a light that flashes uniformly 1800 times per minute. At 1799 flashes per minute, the blades will appear to rotate forward at 1 rpm and, at 1801 flashes per minute, they will appear to rotate backward at 1 rpm.



2.66X:61.16X

Figure 5-15.—Additional tachometers. (A) portable chronometric; (B) mounted resonant reed.

Because the human eye retains images for a fraction of a second, no flicker is seen except at very low speeds. The apparent slow motion is an exact replica of the original higher speed motion, so that the action of a high-speed machine can be analyzed under normal conditions.

When the flashing rate of the light is adjustable, the control can be calibrated in flashes (or revolutions) per minute. The stationary image seen when the flashing rate of the lamp and the rotational rate of a shaft are equal permits very precise speed measurements to be made.

The Strobotac is an electronic flash device, in which the flash duration is very short (on the order of a few millionths of a second), which allows very rapid motion to be arrested.

Figure 5-16 is a photograph of the Strobotac. The box contains a swivel mount with a strobotron lamp in a parabolic reflector, an electronic pulse generator to control the flashing rate, and a power supply that operates from the a-c power line. The flashing rate is controlled by the large knob (see photo), and the corresponding speed in rpm is indicated on an illuminated dial viewed through windows in the knob.

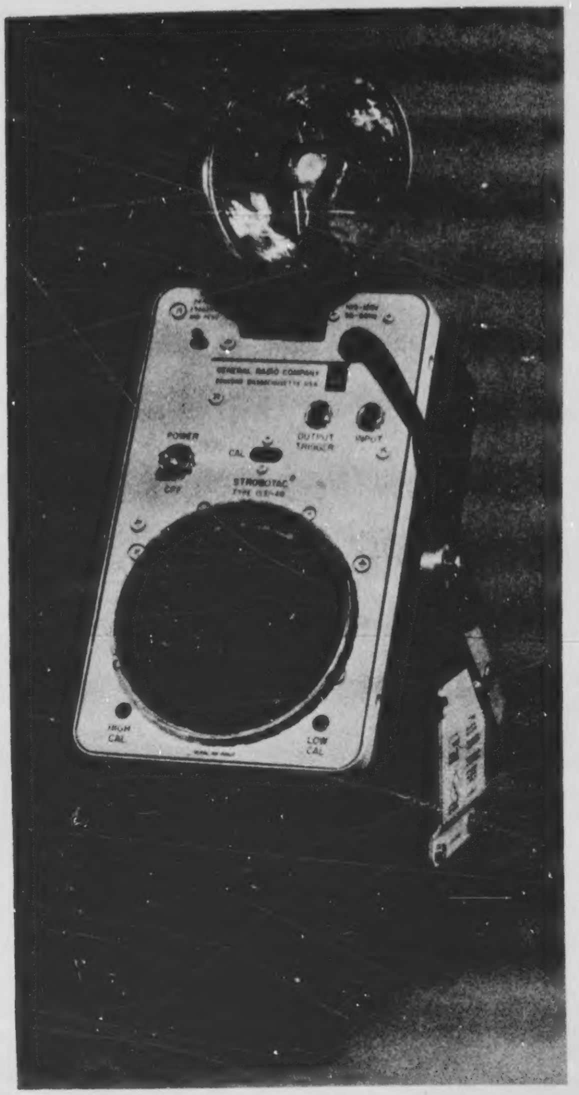
The normal speed range is from 110 to 25,000 rpm. At speeds below 600 rpm flicker becomes pronounced because the human eye cannot retain successive images long enough to create the illusion of continuous motion. The flicker and the low average level of illumination set 600 rpm as the lower limit of speeds used for slow-motion studies. If slow speeds are to be checked, it is necessary to use an external flash with higher intensity than the built-in flash in order to raise the average level of illumination.

Maintenance

The life of the strobotron tube is approximately 250 hours if used at flashing speeds of less than 5000 rpm or 100 hours if used at higher speeds.

If the Strobotac is operated continuously at the higher speeds, the strobotron cathode emission may eventually be reduced to the point where the tube is inoperative. When this happens, the tube usually glows with a dull red color, but will not flash. Flickering is another symptom of low cathode emission.

It is sometimes possible to restore operation by running the tube at low speeds for several hours. Eventually, however, the tube becomes completely inoperative and must be replaced.



140.31(140B)

Figure 5-16.—Strobotac (Type 1531-AB)

OSCILLOSCOPE AN/USM-105A

Oscilloscope AN/USM-105A (fig. 5-17) is a general purpose, high-speed laboratory type oscilloscope designed for shipboard use. It produces a graphical display of simple and complex voltage variations which contain frequency components ranging from zero to 14 megahertz. To simplify operation and the interpretation of the display, the instrument provides calibrated vertical sensitivities, triggered internal sweeps, calibrated sweep times, calibrated expanded sweeps, beam finder, and calibrator.

Oscilloscope AN/USM-105A consists of a major unit and two plug-in units. The major unit, Oscilloscope OS-82A/USM-105, contains the power supplies, horizontal amplifier, sweep generator, main vertical amplifier, cathode-ray tube (CRT), calibrator, and the controls associated with these circuits. Oscilloscope Subassembly, Vertical Channel, Dual Trace Preamplifier MX-2930A/USM-105 is a plug-in preamplifier to the main vertical amplifier. The dual trace preamplifier contains two separate voltage channels each with its own controls. An electronic switch, controlled from the front panel, connects one channel or the other to the main vertical amplifier and thereby determines the vertical presentation on the CRT. To produce a dual trace, the electronic switch alternates channels, either on alternate sweeps, or continuously at a one-megahertz rate. Oscilloscope Subassembly, Horizontal Channel, Auxiliary Plug-in Unit MX-3078/USM-105A permits single-sweep operation and external intensity modulation.

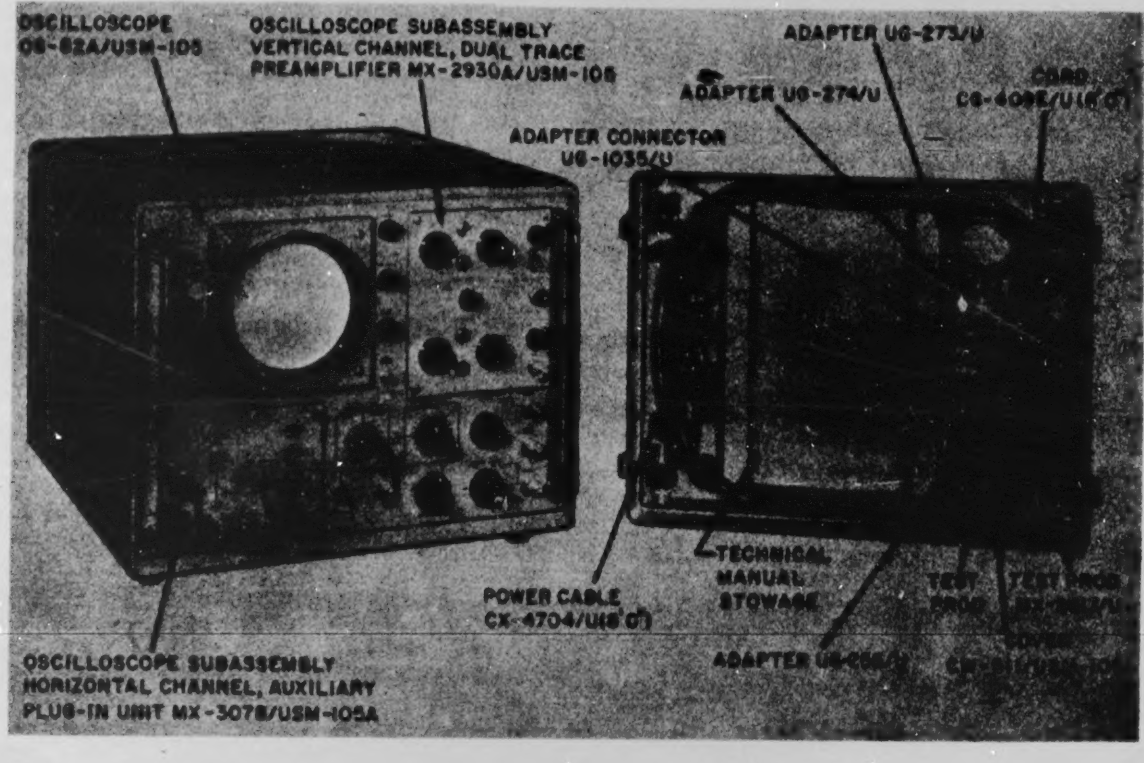
The test prods are used to decrease circuit loading. The one megohm input impedance of the vertical and horizontal circuits plug the shunt capacity of a cable connecting the oscilloscope to the test circuit may degrade the operation of the circuit under test. The test prod increases input impedance to 10 megohms shunted by 10 picofarads. The test prod also introduces a 10:1 voltage division which must be considered when translating waveform deflection on the CRT into volts.

The test prod has an adjustable compensating capacitance so the prod can be matched exactly to a particular input of the oscilloscope. The procedure for matching a test prod to the Channel A input of the dual-trace preamplifier is given below. The procedure is similar for matching a test prod to any other input.

1. Connect test prod cable to Channel A INPUT, (fig. 5-18).

2. Select CHANNEL A and set Channel A SENSITIVITY switch to .02 VOLTS/CM.

3. Set SWEEP TIME switch to .5 MILLISECONDS/CM, HORIZONTAL DISPLAY switch to X1, TRIGGER SOURCE switch to INT, and SWEEP MODE control to PRESET.


OSCILLOSCOPE
OS-62A/USM-105
OSCILLOSCOPE SUBASSEMBLY
VERTICAL CHANNEL, DUAL TRACE
PREAMPLIFIER MX-2930A/USM-105
ADAPTER UG-273/U
ADAPTER UG-274/U
CORD
CG-409E/U
ADAPTER CONNECTOR
UG-1035/U
TECHNICAL
MANUAL
STOWAGE
TEST
PROD
TEST PROD
COVER
POWER CABLE
CX-4704/U(6'0")
ADAPTER
OSCILLOSCOPE SUBASSEMBLY
HORIZONTAL CHANNEL, AUXILIARY
PLUG-IN UNIT MX-3078/USM-105A

1.86.5

Figure 5-17.—Oscilloscope AN/USM-105A.

4. Set CALIBRATOR switch to 1 and touch test prod to VOLTS terminal of calibrator output. A square wave five centimeters high should appear on the CRT.

5. Loosen knurled locknut just behind rear flange on test prod body.

6. Hold test prod behind locknut and rotate rear flange to give flat-topped square wave.

7. Tighten knurled locknut without disturbing adjustment. This completes the adjustment.

Operation

The following procedures give step-by-step operating instructions for Oscilloscope AN/USM-105A. The first procedure gives complete instructions for single-channel operation. The remaining procedures give instructions peculiar only to the modes of operation with which they are concerned.

Before making any test or measurements, allow the instrument about 5-minutes warmup. Rotate INTENSITY control fully counterclockwise before turning instrument on to prevent accidental burning of the CRT face during warm-up.

Use the test prods and other accessories furnished with the oscilloscope as necessary.

Single Trace Operation-Internal Sweep

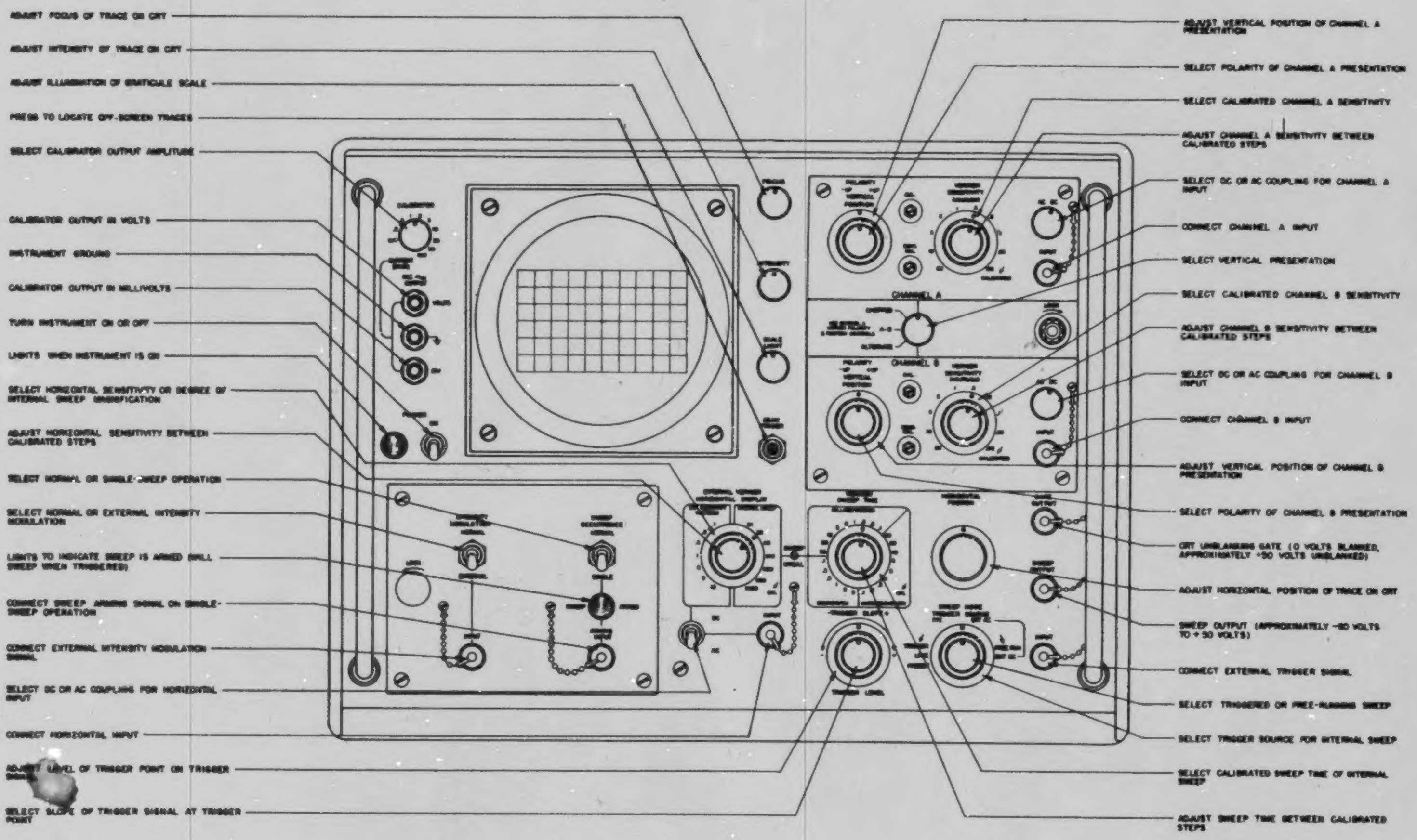
1. Connect vertical signal to INPUT of Channel A.

2. Set Vertical Presentation switch to CHANNEL A.

3. Set SENSITIVITY switch for Channel A as desired. (Set VERNIER to CALIBRATED for calibrated sensitivity.)

4. Set input coupling for a-c or d-c coupling as desired.

5. Set POLARITY switch to + UP or - UP as desired.


ADJUST FOCUS OF TRACE ON CRT
ADJUST INTENSITY OF TRACE ON CRT
ADJUST ILLUMINATION OF GRATICULE SCALE
PRESS TO LOCATE OFF-SCREEN TRACES
SELECT CALIBRATOR OUTPUT AMPLITUDE
CALIBRATOR OUTPUT IN VOLTS
INSTRUMENT GROUND
CALIBRATOR OUTPUT IN MILLIVOLTS
TURN INSTRUMENT ON OR OFF
LIGHTS WHEN INSTRUMENT IS ON
SELECT HORIZONTAL SENSITIVITY OR DEGREE OF INTERNAL SWEEP MAGNIFICATION
ADJUST HORIZONTAL SENSITIVITY BETWEEN CALIBRATED STEPS
SELECT NORMAL OR SINGLE-SWEEP OPERATION
SELECT NORMAL OR EXTERNAL INTENSITY MODULATION
LIGHTS TO INDICATE SWEEP IS ARMED (WILL SWEEP WHEN TRIGGERED)
CONNECT SWEEP ARMING SIGNAL ON SINGLE-SWEEP OPERATION
CONNECT EXTERNAL INTENSITY MODULATION SIGNAL
SELECT DC OR AC COUPLING FOR HORIZONTAL INPUT
CONNECT HORIZONTAL INPUT
ADJUST LEVEL OF TRIGGER POINT ON TRIGGER SIGNAL
SELECT SLOPE OF TRIGGER SIGNAL AT TRIGGER POINT
ADJUST VERTICAL POSITION OF CHANNEL A PRESENTATION
SELECT POLARITY OF CHANNEL A PRESENTATION
SELECT CALIBRATED CHANNEL A SENSITIVITY
ADJUST CHANNEL A SENSITIVITY BETWEEN CALIBRATED STEPS
SELECT DC OR AC COUPLING FOR CHANNEL A INPUT
CONNECT CHANNEL A INPUT
SELECT VERTICAL PRESENTATION
SELECT CALIBRATED CHANNEL B SENSITIVITY
ADJUST CHANNEL B SENSITIVITY BETWEEN CALIBRATED STEPS
SELECT DC OR AC COUPLING FOR CHANNEL B INPUT
CONNECT CHANNEL B INPUT
ADJUST VERTICAL POSITION OF CHANNEL B PRESENTATION
SELECT POLARITY OF CHANNEL B PRESENTATION
CRT UNBLANKING GATE (0 VOLTS BLANKED, APPROXIMATELY +30 VOLTS UNBLANKED)
ADJUST HORIZONTAL POSITION OF TRACE ON CRT
SWEEP OUTPUT (APPROXIMATELY -30 VOLTS TO + 30 VOLTS)
CONNECT EXTERNAL TRIGGER SIGNAL
SELECT TRIGGERED OR FREE-RUNNING SWEEP
SELECT TRIGGER SOURCE FOR INTERNAL SWEEP
SELECT CALIBRATED SWEEP TIME OF INTERNAL SWEEP
ADJUST SWEEP TIME BETWEEN CALIBRATED STEPS
CHANNEL A
CHANNEL B

1.86.5

Figure 5-18.— Front panel controls and connectors.

6. Set TRIGGER SOURCE as desired. If external trigger is used, connect it to trigger source INPUT.
7. Set INTENSITY MODULATION and SWEEP OCCURRENCE switches to NORMAL.
8. Set HORIZONTAL DISPLAY switch to INTERNAL SWEEP X1.
9. Set SWEEP MODE to PRESET.
10. Set TRIGGER SLOPE switch for triggering on positive or negative slope of trigger signal as desired.
11. Set TRIGGER LEVEL control to O.
12. Set SWEEP TIME switch for desired sweep time (set VERNIER control to CAL for calibrated sweep time).
13. Set INTENSITY control as desired.
14. Adjust VERTICAL POSITION and HORIZONTAL POSITION controls as desired.
15. If trace does not appear on screen, press BEAM FINDER switch and readjust position controls to center trace.
16. Adjust TRIGGER LEVEL control to start trace at desired level of trigger signal. It may be necessary to switch SWEEP MODE control from PRESET and select a better setting for the particular trigger signal being used.

NOTE: To use Channel B for single trace operation follow this procedure, substituting Channel B controls and terminals.

Dual Trace Operation

1. Connect one signal to INPUT connector of Channel A and set Channel A controls as desired.
2. Connect second signal to INPUT of Channel B and set Channel B controls as desired.
3. Set Vertical Presentation switch to CHOPPED for display of both signals on same sweep, to ALTERNATE for display of signals on alternate sweeps.

NOTE: For best results, use external triggering.

Differential Operation

1. Connect one signal to INPUT of Channel A.
2. Set SENSITIVITY switch of Channel A as desired.
3. Connect second signal to INPUT of Channel B.
4. For best results, set SENSITIVITY of Channel B to same setting as SENSITIVITY of Channel A.
5. Set POLARITY switch of Channel A to + UP.
6. Set vertical Presentation switch to A-B.
7. If vertical adjustment is necessary, use VERTICAL_POSITION control of Channel A.

Internal Sweep Magnification

1. Set SWEEP TIME switch as desired. (Set VERNIER control to CAL for calibrated sweep time.)
2. Set HORIZONTAL DISPLAY switch to INTERNAL SWEEP X1 (unmagnified sweep position).
3. Adjust HORIZONTAL POSITION control to place portion of trace to be magnified under vertical center line of graticule (lined scale on the screen of the CRT).
4. Set HORIZONTAL DISPLAY to desired magnification.
5. Readjust INTENSITY as necessary.
6. If selected sweep time with magnification is less than minimum calibrated sweep time (0.02 microseconds/cm), SWEEP UNCAL indicator will light indicating that sweep time is no longer calibrated.

External Horizontal Input

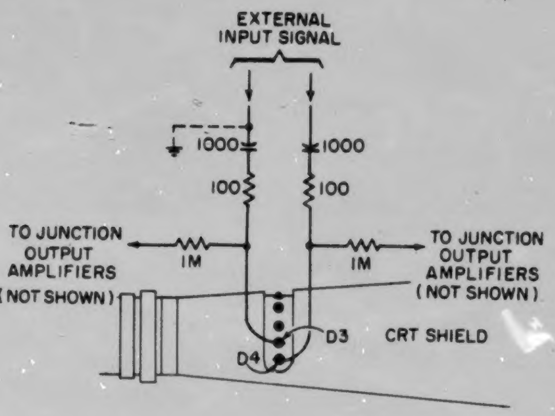
1. Connect horizontal signal to horizontal INPUT connector.
2. Set horizontal input coupling switch to a-c or d-c as desired.
3. Set HORIZONTAL DISPLAY to desired external sensitivity.
4. Adjust HORIZONTAL POSITION control as desired.

Intensity Modulation

1. Set INTENSITY MODULATION switch to EXTERNAL.
2. Connect modulation signal to external intensity modulation INPUT connector. Positive signal of 20 volts peak will blank trace from normal intensity; negative signal will brighten trace.

Single Sweep Operation

1. Set SWEEP OCCURRENCE switch to NORMAL.
2. Set SWEEP TIME switch as desired. (Set VERNIER control to CAL for calibrated sweep time.)


EXTERNAL INPUT SIGNAL
1000
1000
100
100
TO JUNCTION OUTPUT AMPLIFIERS (NOT SHOWN)
IM
IM
TO JUNCTION OUTPUT AMPLIFIERS (NOT SHOWN)
D3
CRT SHIELD
D4

124.224

Figure 5-19.—Direct connection to deflection plates of cathode-ray tube.

3. Set TRIGGER SOURCE switch according to trigger signal used.
4. Set SWEEP MODE as desired.
5. Set TRIGGER SLOPE as desired.
6. Adjust TRIGGER LEVEL as desired.
7. Set SWEEP OCCURRENCE to SINGLE.
8. To arm sweep circuit, switch SWEEP MODE just out of PRESET and back to PRESET, or apply pulse 1 to 4 microseconds long and +15 to +25 volts peak to ARMING INPUT connector.
9. SWEEP ARMED indicator will light. After sweep, indicator will extinguish, and sweep circuit will remain disabled until rearmed.

Connecting Signal Directly to CRT Deflection Plates

CAUTION

Do not contact CRT deflection plate terminals with instrument turned on. These terminals are normally operated about +200 volts.

1. Turn oscilloscope off and remove access plate on top of cabinet.
2. Remove leads from vertical deflection plate terminals D3 and D4 (fig. 5-19).
3. Connect components as shown in figure 5-15. Use capacitors with good high-frequency response. Front-panel VERTICAL POSITION control remains effective.
4. For single ended input, ground common signal lead as shown by dashed ground lead in figure 5-17. For balanced input, leave both signal leads ungrounded.
5. Turn oscilloscope on. Use external signal to trigger sweep.

Maintenance

Preventive maintenance for oscilloscopes consists of periodic cleaning and inspections. No lubrication is required. Use dry compressed air, or a dry cloth and a soft brush for cleaning. It may be necessary to use a dry-cleaning solvent to clean the ceramic insulators, but care should be taken not to remove the special paint. Do not use solvent on the chassis as it may soften the tropicalizing paint. Compressed air or a brush is best for cleaning the electron tubes. Keep all tubes that operate at a high temperature clean, as a layer of dust will interfere with heat radiation and raise the operating temperature.

Remove all tubes from their sockets periodically and inspect the pins and sockets. Remove any corrosion from the pins with crocus cloth. Check the plate connections of the high-voltage rectifier tubes to ensure that they are clean and tight. Remove all fuses and check for looseness and corrosion.

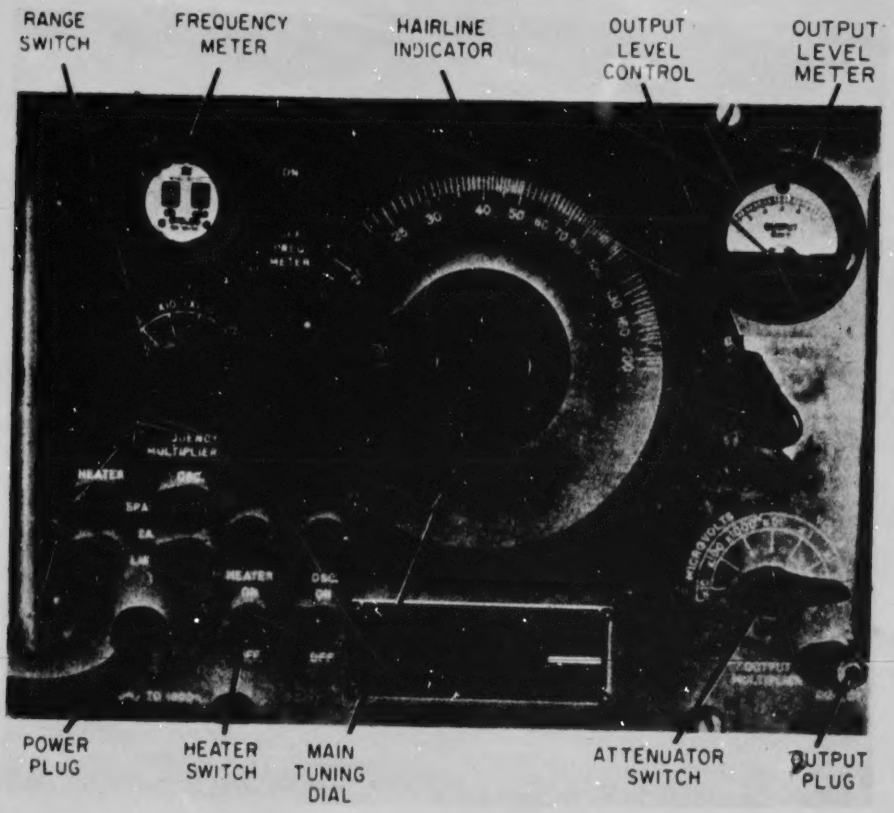
Inspect the AN/USM-105A air filter frequently and clean if necessary. Check the fan motor brushes at least monthly.

SIGNAL GENERATORS

Signal generators are test equipments that generate a-c signals. They are used for signal tracing, aligning tuned circuits, making sensitivity measurements, and frequency measurements. Audio frequency signal generators (audio oscillators) have a frequency range of from 20 to 20,000 hertz (up to 200 kHz to 10,000 mHz. As an IC Electrician, you will be concerned with audio oscillators.

AUDIO OSCILLATOR TS-382D/U

A representative audio oscillator, the TS-382D/U (fig. 5-20) generates a-c voltages ranging from 20 to 200,000 hertz at amplitudes which may be varied continuously from zero to 10 volts. The set contains thermostatically controlled heaters which reduce the time required for the instrument to reach a stable operation temperature. The heaters also permit satisfactory operation in arctic climates. The audio oscillator operates


RANGE SWITCH
FREQUENCY METER
HAIRLINE INDICATOR
OUTPUT LEVEL CONTROL
OUTPUT LEVEL METER
POWER PLUG
HEATER SWITCH
MAIN TUNING DIAL
ATTENUATOR SWITCH
OUTPUT PLUG

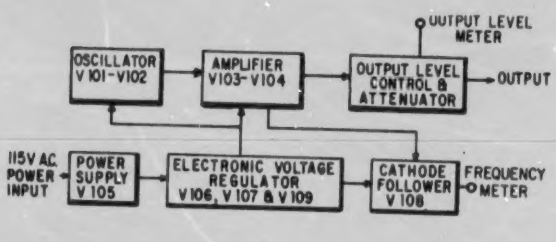
20.338.1

Figure 5-20.—Audio oscillator TS-382D/U.

from a 115-volt a-c source, at a line frequency of 5 hertz to 1600 hertz.

Major Sections

The circuit (fig. 5-21) consists of an oscillator section which generates the audio voltage, an amplifier which isolates the oscillator from the external circuit and amplifies the audio voltage, an output level metering circuit with an attenuator, a power supply, an electronic voltage regulating system, and a cathode follower which isolates it from the remainder of the circuit.

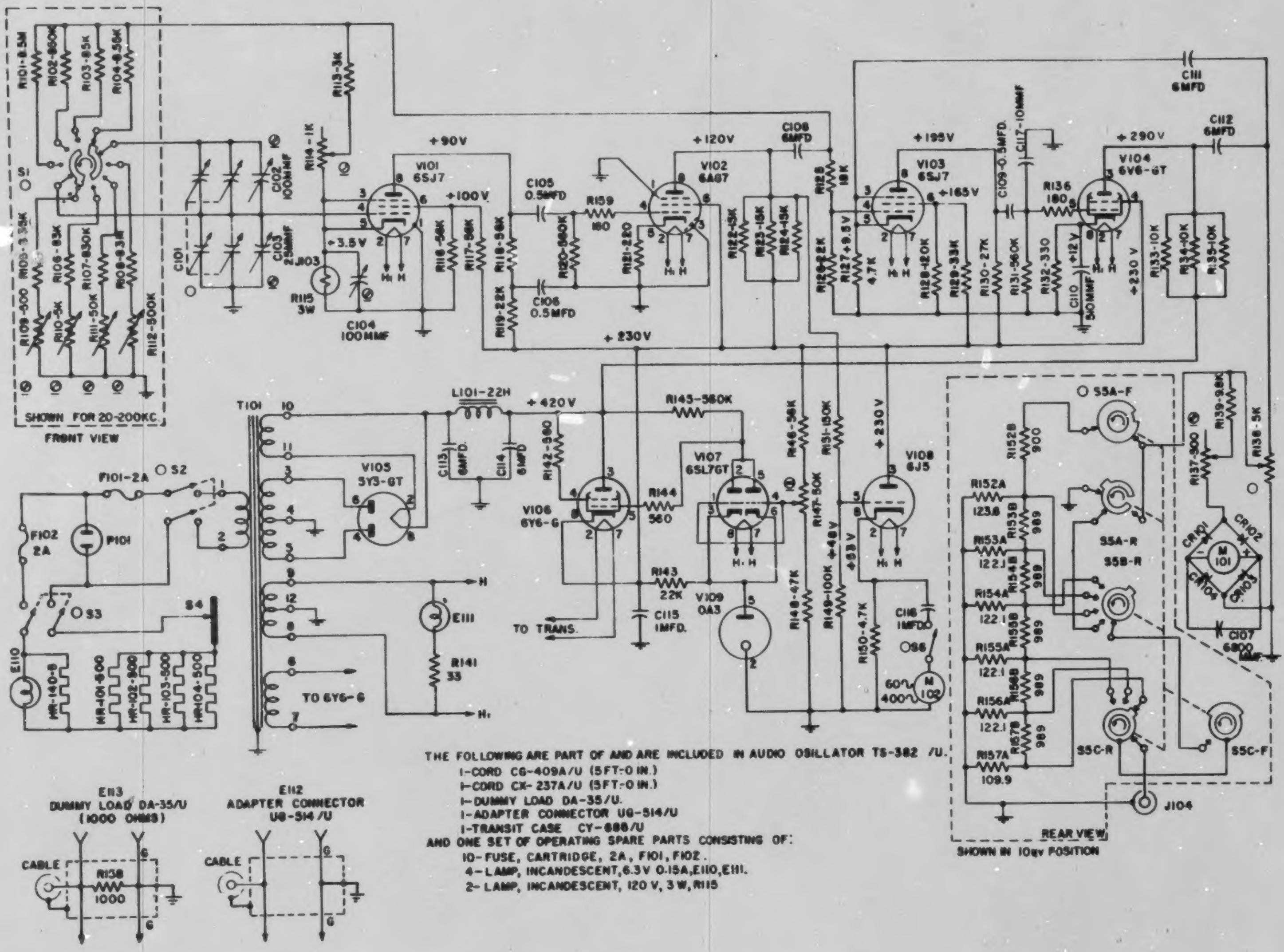

OUTPUT LEVEL METER
OSCILLATOR V101-V102
AMPLIFIER V103-V104
OUTPUT LEVEL CONTROL & ATTENUATOR
OUTPUT
115V AC POWER INPUT
POWER SUPPLY V105
ELECTRONIC VOLTAGE REGULATOR V106, V107 & V109
CATHODE FOLLOWER V108
FREQUENCY METER

20.338.2

Figure 5-21.—Block diagram of TS-382D/U.

OSCILLATOR.—The oscillator section (fig. 5-22), includes tubes V101 to V102 and consists basically of a two-stage resistance coupled amplifier which is caused to oscillate by the use of positive feedback.

OUTPUT AMPLIFIER.—The output section consists of a two-stage resistance coupled amplifier employing tubes V103 and V104. Negative feedback is used to minimize distortion and provide uniform output. The output is constant within two db, over the frequency range covered by the instrument.


S1
R101-8.5M
R102-880K
R103-85K
R104-8.58K
R109-500
R105-3.35K
R106-83K
R107-830K
R108-8.3K
R110-5K
R111-50K
R112-800K
SHOWN FOR 20-200KC.
FRONT VIEW
C101
C102 100MMF
C103 25MMF
R113-3K
R114-1K
J103
R115 3W
C104 100MMF
+3.5V
+90V
V101 6SJ7
+100V
R116-56K
R117-56K
R118-56K
R119-22K
C105 0.5MFD
C106 0.5MFD
R120-560K
R159 180
R121-220
+120V
V102 6A87
R122-15K
R123-15K
R124-15K
C108 6MFD
R125 18K
R126-22K
R127+9.5V
4.7K
+195V
V103 6SJ7
+165V
R128-120K
R129-33K
R130-27K
R131-560K
C109-0.5MFD.
C117-10MMF
R132-330
R136 180
C110 510MMF
+12V
+290V
V104 6V6-GT
+230V
R133-10K
R134-10K
R135-10K
C111 6MFD
C112 6MFD
+230V
T101
L101-22H
C113 6MFD
C114 6MFD
+420V
V105 5Y3-GT
R142-560
V106 6Y6-G
R143-560K
R144 560
V107 6SL7GT
R143 22K
C115 1MFD
V109 0A3
TO TRANS.
R146-56K
R147-50K
R148-47K
R149-100K
+48V
R151-150K
+88V
+230V
V108 6J5
R150-4.7K
C116 1MFD
S6
60~
400~
M 102
F101-2A
S2
F102 2A
P101
S3
S4
E110
HR-140-8
HR-101-500
HR-102-500
HR-103-500
HR104-500
E111
R141 33
H
H1
TO 6Y6-G
S5A-F
R152B 900
R152A 123.6
R153B 989
R153A 122.1
R154B 989
R154A 122.1
R155B 989
R155A 122.1
R156B 989
R156A 122.1
R157B 989
R157A 109.9
S5A-R
S5B-R
S5C-R
S5C-F
J104
REAR VIEW
SHOWN IN 10qv POSITION
R137-500
R139-9.8K
R138-5K
CR101
CR102
CR103
CR104
M 101
C107 6800 MMF
E113
DUMMY LOAD DA-35/U
(1000 OHMS)
CABLE
R138
1000
E112
ADAPTER CONNECTOR
UG-514/U
CABLE
G

THE FOLLOWING ARE PART OF AND ARE INCLUDED IN AUDIO OSILLATOR TS-382 /U.
1-CORD CG-409A/U (5FT-0 IN.)
1-CORD CX-237A/U (5FT-0 IN.)
1-DUMMY LOAD DA-35/U.
1-ADAPTER CONNECTOR UG-514/U
1-TRANSIT CASE CY-688/U
AND ONE SET OF OPERATING SPARE PARTS CONSISTING OF:
10-FUSE, CARTRIDGE, 2A, F101, F102.
4-LAMP, INCANDESCENT, 6.3V 0.15A, E110, E111.
2-LAMP, INCANDESCENT, 120 V, 3 W, R115

140.32

Figure 5-22.—Audio oscillator TS-382D/U, schematic diagram.

OUTPUT SYSTEM.—The output system consists of an output level meter, a gain control, and a six-section ladder type attenuator, consisting of a series of resistors. The output meter operates from a full-wave type rectifier circuit in which germanium crystals are used as rectifying elements. The gain control is inserted in the circuit immediately preceding the output meter in order to set the voltage level at the input to the ladder attenuator. The ladder attenuator is calibrated on the basis of the instrument working into its rated load of 1,000 ohms.

POWER SUPPLY.—The power supply is designed to deliver filament voltage to all the tubes and to supply well-filtered d-c voltage to the plates and screen grids. The power transformer supplies all filament voltages in addition to high voltage to the full-wave rectifier V105, which converts the a-c voltage to pulsating direct current. The rectified wave passes through a single section pi filter where the a-c component is removed.

VOLTAGE REGULATING SYSTEM.—The filtered direct current is regulated by a degenerative type voltage regulator employing tubes V106, V107, and V109. The regulator is designed to supply a constant voltage of 230 volts to the plate circuit of the various tubes.

FREQUENCY METER.—A vibrating reed type meter permits accurate check of the output frequency of the oscillator at 60 and 400 Hz. The meter has been factory adjusted to an accuracy of three-tenths of one percent. This meter, is isolated from the second oscillator tube V102 by a cathode follower stage V108 to prevent shifts in frequency when the frequency meter is in operation.

STAND-BY HEATER.—Five strip heaters are used to decrease the time required for the unit to reach stable operation and to permit satisfactory operation incolder climates. These strip heaters are controlled by a built-in thermostat, calibrated to maintain the temperature at 20° C. An ON-OFF switch and an indicator light are included in the heater circuit.

Operation

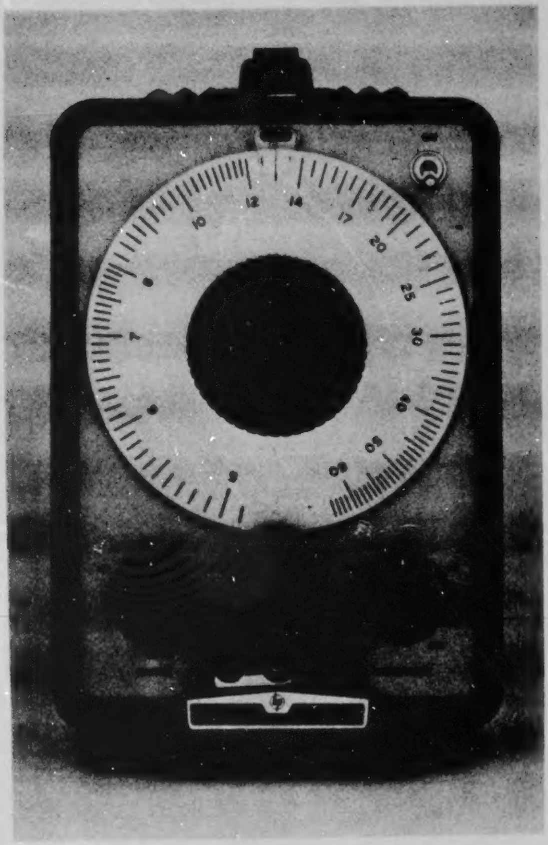
Audio Oscillator TS-382D/U should be allowed a warmup period of at least 15 minutes, in order to reach a stable operating temperature. Audio frequency output is taken from the oscillator at the output connector on the lower right-hand side of the front panel (fig. 5-20). The output cable may be used either with the adapter connector (UG-514/U), or the dummy load (DA-35/U) (not shown) marked 1,000 OHM LOAD, for high impedances. Use of the dummy load with high impedance external loads maintains the accuracy of the metering circuit calibration.

The controls of Audio Oscillator TS-382D/U and their functions are as follows (fig. 5-20):

Control	Function
OSC: On, Off	Oscillator Power Switch
HEATER: On, Off	Switch for stand-by heater
RANGE	Selects frequency range
X1, X10, X100, X1000	
Main Tuning Dial (Hairline Indicator)	Selects frequency within each range
OUTPUT LEVEL (METER)	Indicates voltage input to attenuator
OUTPUT LEVEL (CONTROL)	Adjusts voltage input to attenuator
ATTENUATOR	Reduces output voltage in sub-multiples of ten.

STARTING PROCEDURE.—Plug the female end of the power cable into the power socket in the lower left-hand corner of the front panel. With the OSC switch and HEATER switch in OFF positions, plug the male end of the power cable into a 115 volt a-c source. Check the line voltage with a voltmeter to be sure that it is correct. Throw the OSC switch to ON position and check to see that the pilot lamp directly above the switch lights. Allow the instrument to warm up for at least 15 minutes. At low ambient temperatures, it is advisable to turn the HEATER switch to the ON position.

SELECTING FREQUENCY.—Any frequency from 20 to 200,000 Hz may be selected by setting the main tuning dial and the range switch so that the two readings, when multiplied together, equal the desired frequency. For example, to select an output frequency of 52,000 Hz, set the main tuning dial to 52 and the range switch to X1000. Do not force the main tuning dial beyond



140.144
Figure 5-23.— Model 200CD wide range oscillator.

its normal travel as it may destroy the calibration of the instrument.

SELECTING OUTPUT VOLTAGE. — Voltages from zero to 10 volts may be selected by using the OUTPUT LEVEL control in conjunction with the attenuator switch. The attenuator is calibrated in seven decade steps so that with the output meter set to 10 volts, output voltages of 10 volts to 10 microvolts can be obtained by simply switching the attenuator. For intermediate values of output voltage, the OUTPUT LEVEL control is varied so that the output meter reads the desired voltage. The attenuator switch is then set so that its value, multiplied by the output meter reading, gives the desired output voltage level. For example, to obtain an output voltage of 0.04 volts, set the meter by means of the OUTPUT LEVEL control to read 4 volts, and set the ATTENUATOR switch to the .01 position. The output voltage will then be the meter reading multiplied by the attenuator setting, or 0.04 volts.

STOPPING PROCEDURE. — The oscillator is turned off by throwing OSC switch to OFF position. If the heaters have been used, they should also be turned OFF. Remove the power plug first from the supply line and then from the front panel, remove the output cable, and replace the unit in its transit case.

Maintenance

The following periodic inspections are recommended for Audio Oscillator TS-382D/U at the intervals indicated:

Weekly:	Inspect front panel of Audio Oscillator, check fuseholders, indicator lamp assemblies, power plug, output plug, cables, dummy load, and adapter connector.
Monthly:	Check tightness of knobs.
Semiannually:	Inspect front panel, tubes, and tube socket, switches, variable capacitors, thermostat contacts, terminal boards, and chassis.

To check that the Audio Oscillator is operating properly, set the main tuning dial to 60, and the range switch to X1 (the lowest frequency range). This sets the frequency of the oscillator at 60 Hz. Turn the tuning dial back and forth slightly until the reed in the Frequency Meter marked 60 hertz vibrates with maximum amplitude. This point should be correct within one division.

Similarly, the output at 400 Hz may be checked by setting the main tuning dial to 40 and the range switch to X10. The main dial setting should be correct within 1 1/2 divisions when the 400 hertz reed vibrates with maximum amplitude. Turn FREQ. METER switch to OFF position after checking the frequency calibration.

Use a clean, dry lint-free cloth or a dry brush for cleaning. All control knobs should be tightened using an Allen wrench. Do not loosen the three setscrews on the main tuning dial plate behind the knob on the main dial as the frequency calibration of the instrument will be destroyed.

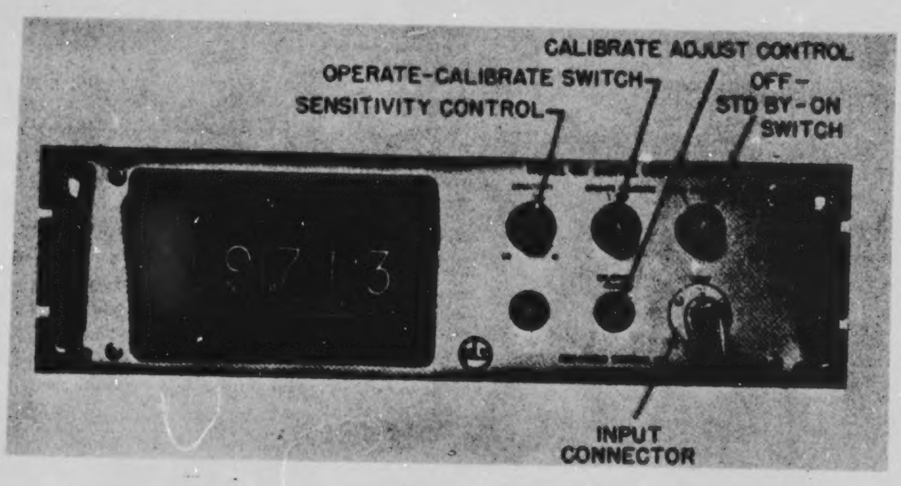

CALIBRATE ADJUST CONTROL
OPERATE-CALIBRATE SWITCH
SENSITIVITY CONTROL
OFF-STD BY-ON SWITCH
INPUT CONNECTOR

Figure 5-24.—Digital voltmeter, model 481. 151.104

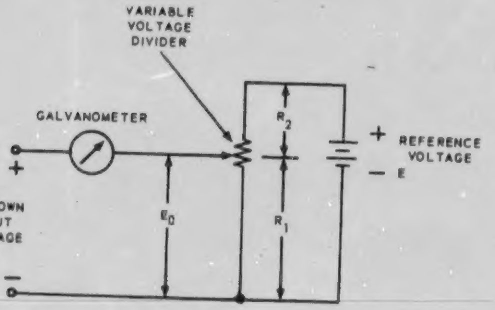
Should the contacts of the RANGE switch or the ATTENUATOR switch become covered with a heavy accumulation of dust, dry compressed air of not more than five pounds pressure may be used, followed by careful cleaning with a small camel's hair brush. Care must be exercised when using the brush, not to damage any of the resistors mounted on these switches.

No lubrication of any kind is required for Audio Oscillator TS-382D/U. The main tuning capacitor and the associated panel bearing have been lubricated at the factory and do not require further lubrication.

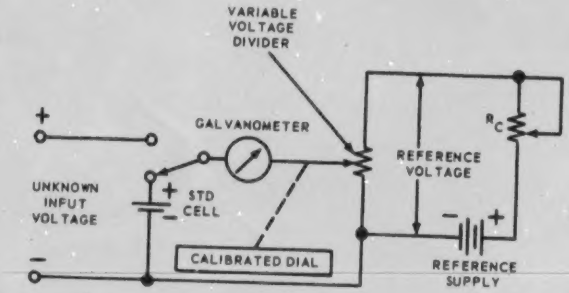
Do not tamper with any of the alignment adjustments as these will affect the frequency calibration of the instrument. Removal of any tube other than those in the power section involves recalibration of the oscillator. Tubes V105, V106, V107, and V109 may be replaced without recalibrating the instrument.

Audio Oscillator (200CD)

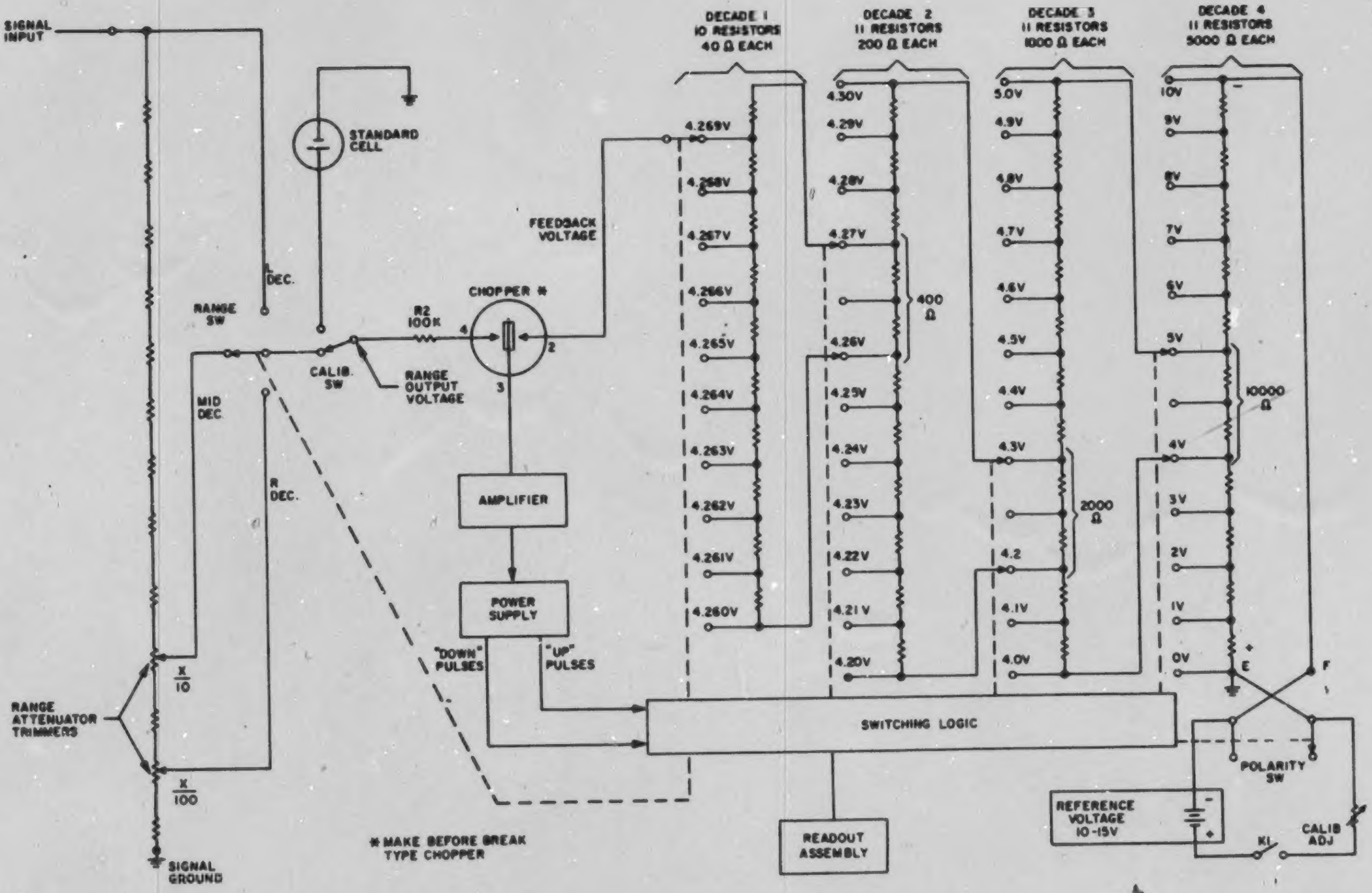
At times the IC Electrician may have to substitute another audio oscillator for the TS-382D/U. When it becomes necessary to do so,


VARIABLE VOLTAGE DIVIDER
GALVANOMETER
R_2
+
REFERENCE VOLTAGE
− E
+
UNKNOWN INPUT VOLTAGE
E_0
R_1
−

151.105
Figure 5-25.—Basic operation principles of a digital voltmeter.


VARIABLE VOLTAGE DIVIDER
+
GALVANOMETER
R_C
REFERENCE VOLTAGE
UNKNOWN INPUT VOLTAGE
+ STD CELL −
−
CALIBRATED DIAL
− +
REFERENCE SUPPLY

151.106
Figure 5-26.—Potentiometer with calibration rheostat.


SIGNAL INPUT
STANDARD CELL
RANGE SW
L DEC.
MID DEC.
R DEC.
CALIB. SW
R2 100K
RANGE OUTPUT VOLTAGE
CHOPPER *
4
2
3
FEEDBACK VOLTAGE
AMPLIFIER
POWER SUPPLY
"DOWN" PULSES
"UP" PULSES
RANGE ATTENUATOR TRIMMERS
X/10
X/100
SIGNAL GROUND
* MAKE BEFORE BREAK TYPE CHOPPER
DECADE 1 10 RESISTORS 40 Ω EACH
4.269V
4.268V
4.267V
4.266V
4.265V
4.264V
4.263V
4.262V
4.261V
4.260V
DECADE 2 11 RESISTORS 200 Ω EACH
4.30V
4.29V
4.28V
4.27V
4.26V
4.25V
4.24V
4.23V
4.22V
4.21V
4.20V
400 Ω
DECADE 3 11 RESISTORS 1000 Ω EACH
5.0V
4.9V
4.8V
4.7V
4.6V
4.5V
4.4V
4.3V
4.2
4.1V
4.0V
2000 Ω
DECADE 4 11 RESISTORS 5000 Ω EACH
10V
9V
8V
7V
6V
5V
4V
3V
2V
1V
0V
10000 Ω
−
+
E
F
SWITCHING LOGIC
READOUT ASSEMBLY
POLARITY SW
REFERENCE VOLTAGE 10-15V
K1
CALIB ADJ

151.263

Figure 5-27. — Simplified circuit diagram, multirange digital voltmeter, for measuring absolute d-c voltages.

he should borrow, from the Electronic Material Officer (EMO), a Model 200CD Audio Oscillator (fig. 5-23).

This oscillator is simple to operate, having only two switches (off/on and range), and two controls (frequency and amplitude) located on the face of the unit. There are also output terminal provisions for either 600 ohms balanced or unbalanced conditions. The 200CD oscillator weighs less, is smaller, and has a wider frequency output (5 Hz to 600 kHz) than the more advanced TS0382D/U.

DIGITAL VOLTMETER, MODEL 481

When measuring voltage with an instrument that contains a meter movement, the IC Electrician may find it impossible to get a precise reading. Present-day meter movements do not measure as accurately as digital voltmeters, whose internal circuits select ranges automatically and switch upscale or downscale, as necessary, to give a precise readout. Model 481 (fig. 5-24) is typical of the digital voltmeters used aboard ship, although there are other kinds. But if your digital voltmeter is not a Model 481, its basic operation will be essentially the same as the 481's.

The model 481 Digital Voltmeter measures d-c voltages and presents the measured value directly in numerical form on a self-illuminated 4-digit readout. The digital voltmeter is essentially a self-balancing potentiometer. Range changing is automatic. The polarity sign and decimal point are also automatically displayed. Accuracy is ± 0.01 percent over the three ranges which are 0 to ±9.999, ±10.00 to ±99.99, and ±100.0 to ±999.9 volts. The digital voltmeter is designed to operate from 105-to-125 or 210-to-250 volt, 60 Hz power sources. Its primary power requirements are satisfied by most nominal 115- or 230-volt, 60 Hz power line input sources.

PRINCIPLES OF OPERATION

Consider the basic potentiometer circuit shown schematically in figure 5-25. If an unknown voltage is applied at the input terminals and a variable divider adjusted until the voltage E_e is equal in magnitude to the unknown voltage, zero current will flow through the galvanometer. This condition is called balance. Note that in the balanced condition no current is drawn from the input (circuit under test). The unknown voltage can be computed from the formula:

$$\text{Unknown voltage} = \frac{R_1}{R_1 + R_2} \times \text{reference voltage.}$$

If the polarity of the unknown voltage is reversed, the polarity of the reference voltage must also be reversed in order to obtain balance. The galvanometer pointer will then travel in the opposite direction, increasing its displacement from zero (center position) as the magnitude of the unknown voltage increases.

To measure the absolute value of the unknown voltage, the reference voltage must be known. Instead of accurately measuring the reference voltage directly, it can be adjusted to the proper value if an accurately known voltage is available for use as a calibration reference. Therefore, a standard cell (fig. 5-26) of known voltage is connected in place of the unknow voltage. The variable voltage divider dial reading (not shown) is set to this known voltage, and the voltage across the variable voltage divider is adjusted by means of rheostat, R_c, to obtain balance. The potentiometer is now calibrated, or standardized, and ready for use as an absolute voltage-measuring device.

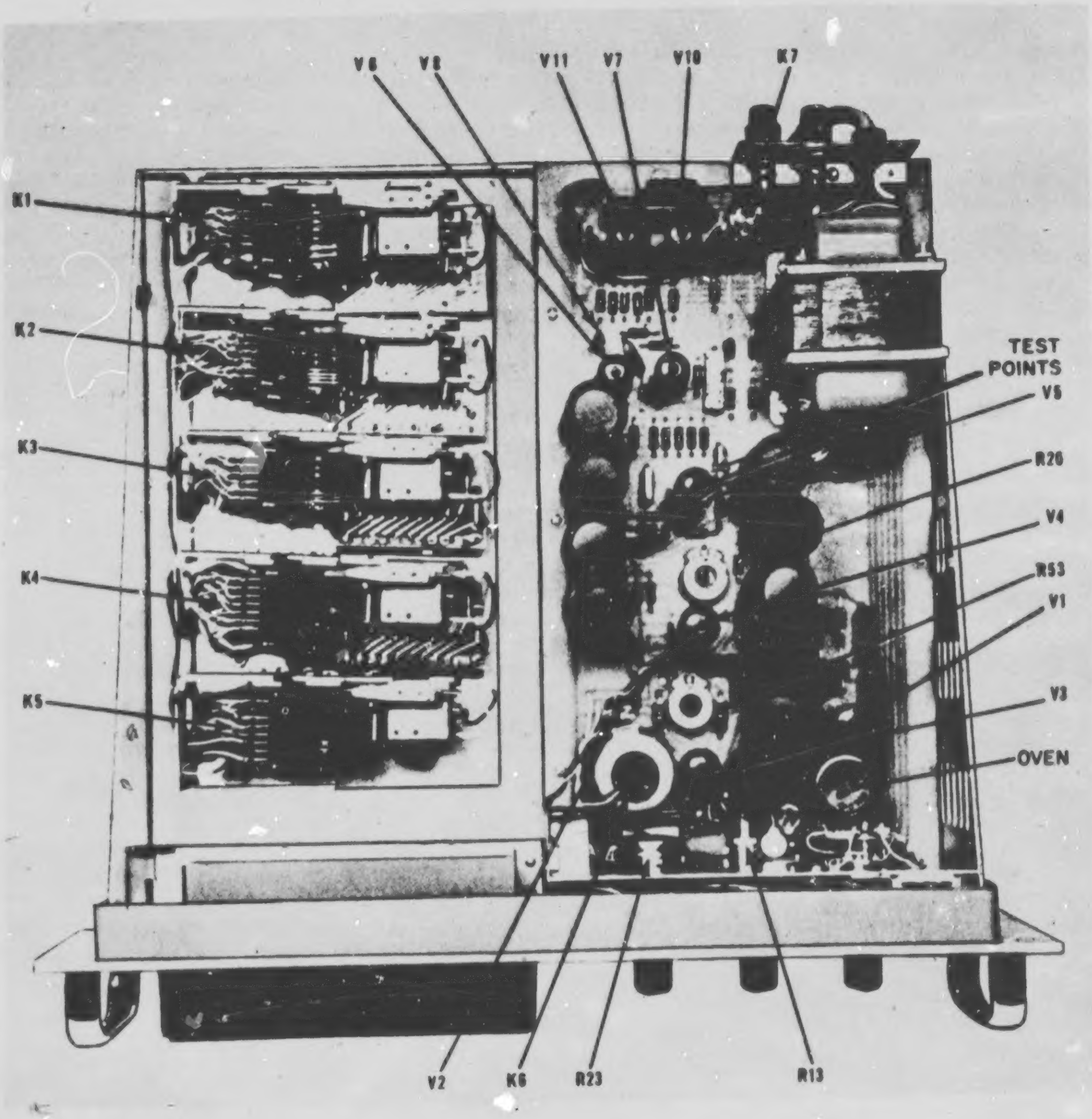
Basically, the operation of the digital voltmeter is the same as the operation of the balanced potentiometer. The main difference is that instead of the balance being achieved manually it is done automatically through the use of an error detection circuit which controls the operation of a series of stepping relays or switches.

There are five stepping relays (fig. 5-27). One automatically selects the proper range (attenuation) and polarity (reference voltage polarity), depending on the amplitude and polarity of the input (unknown) voltage. The other four relays automatically select the proper magnitude of feedback voltage so as to achieve a balance between it and the range output voltage.

The error detection circuit consists of an electromechanical chopper which, in conjunction with a phase-sensitive amplifier, is used to compare the feedback voltage with the range output voltage and produces an error signal if the two voltages are different from each other.

NOTE: The amplifier sensitivity and gain are normally adjusted to produce an error signal if the difference is greater than 0.001 volt.

The error signal will consist of a series of pulses on the amplifier's up-pulse output line if the feedback voltage is less positive than the range output voltage, or a series of pulses



151.108

Figure 5-28.—Digital voltmeter, model 481, top interior view.

on the amplifier's down-pulse output line if the reverse condition is true.

Because of mechanical limitations, wiper blade action on the stepping relays is unidirectional; that is, they can rotate in one direction only. Thus, to select the proper range, polarity, and magnitude of feedback voltage to achieve a balance, the error signal on the amplifier's up-pulse or down-pulse output lines must be routed through the switching logic. This is done in such a fashion as to cause the stepping relays to start at their rest positions, and sequentially cycle through all possible connections until the proper combination is selected.

Whenever a balance is achieved—that is, whenever feedback voltage and the range output voltage are qual in polarity and magnitude—all switching action stops. The readout device then gives an illuminated digital readout of the magnitude and polarity of the unknown voltage, accurate to within ± 0.01 percent.

To eliminate unnecessary switching when the magnitude of the unknown voltage is such as to cause the X10 or X100 range to be selected, a lockout device is incorporated into the switching logic. This causes the most sensitive range to be selected first, and prevents the leftmost readout from registering a zero.

FRONT PANEL CONTROLS AND INDICATORS

The front panel controls and indicators for the Digital Voltmeter Model 481 are shown in figure 5-24.

In the OFF position, the off-standby-on switch disconnects primary power from the voltmeter. The STD BY (standby) position permits the instrument to remain warmed up while stepping switches are turned off to prevent needless operation. This position also permits locking the reading (so that the displayed information remains indefinitely) at any time. The ON position of the switch fully enables the meter after a 15- to 30-second operation delay, controlled by a thermal timer (not shown).

The operate-calibrate switch selects either an operating or calibrating mode of operation for the digital voltmeter.

The calibrate adjust control (located behind a metal protective cap on the front panel) is used to standardize the digital voltmeter as follows:

1. Set the sensitivity control to its full clockwise position.
2. Ensure that the error amplifier gain of the instrument is properly set. To do so, hold the operate-calibrate switch in the CALIBRATE position and slowly turn the calibrate-adjust control in the counterclockwise direction, stopping each time the meter changes reading. The meter reading should change by one digit each time. If the reading changes by more than one digit, or exhibits instability, adjust the internal gain control. (The gain setting procedure is described later.) Repeat turning the calibrate adjust control counterclockwise until ten steps have been satisfactorily completed. Once the gain adjustment is proper, the instrument may be accurately standardized as described in the next paragraph.

While holding the operate-calibrate switch in the CALIBRATE position, slowly turn the calibrate adjust control in the clockwise direction until the meter reads 1019, then stop. The meter is now standardized.

NOTE: The decimal point may appear in any location during the standardization procedure because the d-c voltage range change circuits (which determines the position of the decimal point) become deenergized during this operation.

The sensitivity control varies the gain of the digital voltmeter. When measuring unstable voltages, turn the control counterclockwise until the meter settles at a fixed reading. This reading will be as accurate as the unstable signal measurement will allow. Always turn the sensitivity control fully clockwise for proper operation with stable d-c voltages.

GAIN SETTING

For best results, the digital voltmeter should be operated with the amplifier gain set for advancement in single digit steps. If the amplifier gain is not high enough, the resolution of the meter will be too low. On the other hand, excessively high amplifier gain setting may cause instability of the readout display. To set the amplifier gain, proceed as follows:

1. Remove the cover over the calibrate adjust control on the front panel. Hold the operate-calibrate switch in the CALIBRATE position.
2. After the usual readout has become stable, use a screwdriver to slowly turn the calibrate adjust control, R13 (fig. 5-28) in a counterclockwise direction. Observe the magnitude of the decrease in the readout display. If the value displayed decreases in steps of one digit and does not become unstable, no adjustment of amplifier gain is necessary. If slowly rotating the calibration control in a counterclockwise direction results in a decrease of two or more digits in the rightmost window, the amplifier gain should be increased by slightly turning the amplifier gain control, R20 (fig. 5-28) in a clockwise direction. Again, observe the number of digits by which the readout display decreases when the calibrate adjust control, R13, is slowly turned counterclockwise. Repeat the amplifier gain adjustment, if necessary, to obtain a readout display decrease of one digit in the rightmost windown. If instability develops in the readout

display, turn the amplifier gain control, R20, counterclockwise until the instability just disappears and the readout display decreases in steps of one digit in the rightmost window as the calibrate adjust control, R13, is slowly turned counterclockwise.

HUM CONTROL ADJUSTMENT

Improper adjustment of the hum control will cause considerable error in calibration accuracy. The hum control is accurately set at the factory and should not be reset until it is definitely determined to be out of adjustment. Changing the input tubes can cause the hum control to become incorrectly adjusted. Be sure that the input tube has been aged before resetting the hum control. To adjust hum control, R53, (fig. 5-28) located on the amplifier chassis, proceed as follows:

1. Connect the chassis to ground (the third pin on the power cord is connected to the chassis). Turn on the digital voltmeter and allow a warmup of 15 minutes. Connect an oscilloscope between either of the two test points (fig. 5-28) and ground. Calibrate the oscilloscope in terms of one digit error. To do this, turn the operate-calibrate switch (fig. 5-24) to CALIBRATE and slowly turn calibrate adjust control, R13, (fig. 5-28) counterclockwise. Note the amount of error signal on the oscilloscope. This error is equivalent to one digit if the gain is properly set (as described in the gain setting procedure), and the sensitivity control is advanced fully clockwise.
2. With the operate-calibrate switch (fig. 5-24) set to OPERATE, short the input leads to obtain a reading of +0.000. Set the off-standby-on switch to STD BY. Remove the stepping switch cover. Step range-polarity switch, K5 (fig. 5-28) by hand until the meter reads +00.00. Replace the stepping switch cover. Adjust hum control, R53, for zero error signal as displayed on the oscilloscope. It is necessary that the stepping switch cover, bottom plate, and front panel be in position. The hum control is now properly set.
3. Check the error signal for all ranges (+00.00, +0.000, -000.0, -00.00, -0.000, and +000.0), each time removing the stepping switch cover, stepping range-polarity switch, K5, (fig. 5-28) by hand, and replacing the cover. Do not readjust hum control, R53. The error signal for all range positions should be less than one-half that allowable in changing from one digit to another. If the error exceeds this amount, there are two possible sources of trouble: (1) excessive hum pickup and (2) excessive grid current drawn by the input amplifier tube (not shown). Check all shield and ground leads. Replace the input amplifier tube (type 5751).

NOTE: Do not substitute any other type tube.

STANDARDIZATION ADJUSTMENT

The following standardization procedure is necessary to ensure accurate readout (measurements). Before making any adjustments, make sure that the gain and hum controls are properly set and that the digital voltmeter is connected to ground. Calibrate the voltmeter as described in the calibrate adjust procedure treated earlier. Connect a bank of nine standard cells, each of which has an accuracy of at least 0.01 percent, to the input. The meter reading should be correct to within one digit.

NOTE: Be sure to take into account the internal resistance of the standard cells. The digital voltmeter has an input resistance of 10 megohms, and a 9-volt signal will draw 0.9 microamperes. If the reading is not correct, adjust potentiometer, R11, is located slightly above and to the right of the calibrate adjust control, R13, shown in figure 5-28).

FEEDBACK VOLTAGE LINEARITY TEST

One of the several factors which may affect the accuracy of digital voltmeters is the linearity of the reference voltage divider (fig. 5-27). This reference voltage divider supplies the feedback voltage which is compared to the range output voltage in order to get a readout. Thus, any change in its linearity (or accuracy) will affect the accuracy of the readout. While several methods have been devised for testing the linearity of reference voltage dividers, the one described below is found to be most satisfactory. (It is assumed that the error amplifier gain is properly adjusted before the test is started.)

To perform this test, use as the standard precision voltage divider having a resistance of 1 megohm and an accuracy 5 to 10 times that of the reference voltage divider.

The high resistance is necessary to prevent excessive current drain from the reference supply.

Connect the input of the external precision voltage divider to the input of the reference

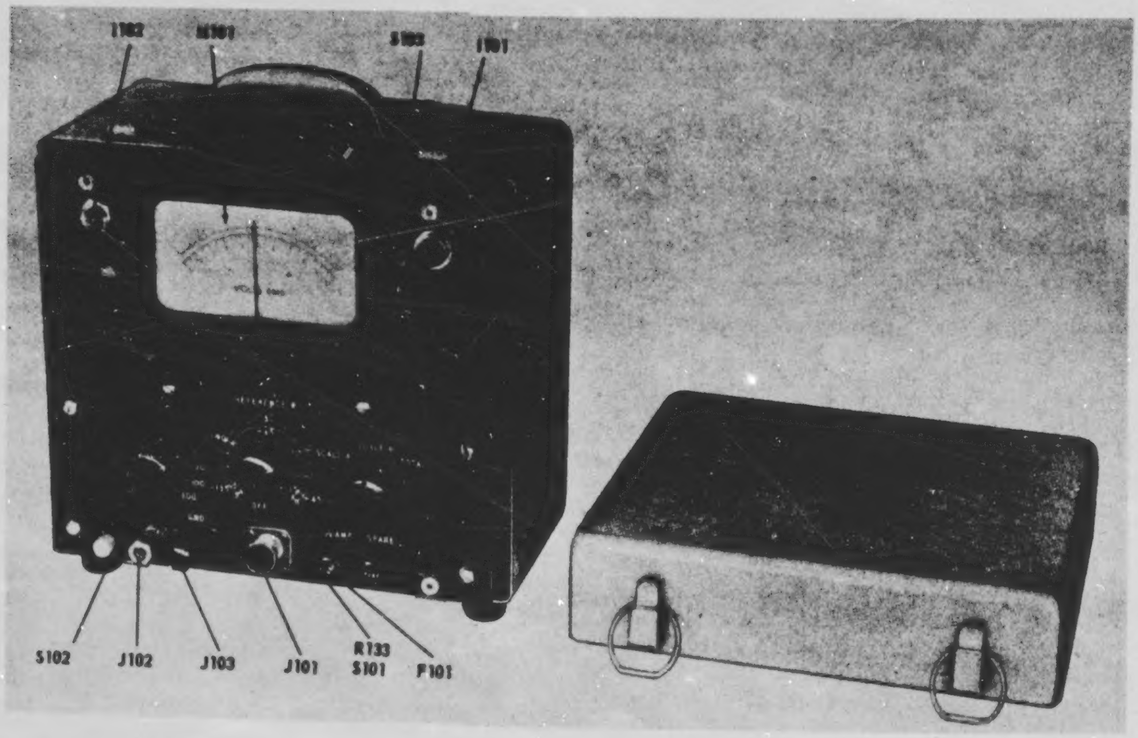


Figure 5-29. — Phase sensitive voltmeter.

140.145

voltage divider in the digital voltmeter. Disconnect the wire from the arm of the operate-calibrate switch. Connect the output of the external precision voltage divider to this terminal. (Observe proper shielding and grounding rules.) Adjust the standard divider at 00000. The visual readout should display a zero in each window. Adjust the standard voltage divider for 99990. The visual readout display should display a 9 in each window. These two readout displays must be obtained for the indicated standard divider settings. If the voltmeter displays digits other than those indicated above for these two end points, an improper circuit condition exists and must be located and corrected before preceeding with this test.

Now set the standard divider for various readings such as: .89990, .7990, .6990, ---- .08990, .0790, ----, 00890, .00790, -------- .00080, .00070. The digital voltmeter readout should be equal to the standard divider setting ± 1 digit.

One advantage of this method of testing voltage divider linearity is that reasonably large (20 percent) diviations in reference voltage from the nominal value of reference voltage have no significant effect upon test accuracy. This is true because the same voltage is furnished to the input of the reference voltage divider as well as the input of the external standard voltage divider. Hence, for equal settings of the two voltage dividers, the output voltages should be equal.

RANGE UNIT ADJUSTMENT

The range unit will require scale factor readjustment only if the range unit resistors change their ohmic value, or if the internal electrical loading of the unit output taps changes. The adjustment method requires several accurate voltage dividers and a stable d-c source. This method permits accurate range unit scale factor adjustment regardless of the inaccuracies present in the digital voltage divider because the voltage divider is always brought back to the same position (same numerical display on the voltmeter, ignoring decimal point location) when the correspondence of scale factors on each range is checked.

As in any other test, proper shielding and grounding techniques must be followed to prevent electrical noise pickup from interfering with the stability and resolution of the digital voltmeter. Also, each range is checked most accurately when the test voltage is as close to full scale for that range as is practicable. The precision voltage divider in the range unit adjustment procedure must be compensated for the electrical loading effect of the digital voltmeter. The accuracy of the external voltage divider should be five to ten times better than the accuracy to which the range unit is to be adjusted.

Access to the range trim potentiometers referred to in the following paragraphs is gained by removing the left-hand protective cap on the front panel (fig. 5-24). These potentiometers are identified by 1000v and 100v on the printed circuit range board.

Adjusting the 100-Volt Range Scale Factor

The following procedure is used:

1. Connect the input terminals of a 10-to-1 precision voltage divider to a stable source of d-c voltage, approximately 95 to 99 volts.
2. Connect the input terminals of the digital voltmeter under test to the input of the voltage divider. Observe the readout display and waveform at the error amplifier test points.
3. Connect the input terminals of the voltmeter to the output terminals of the voltage divider. Observe the readout display and the error amplifier waveform.
4. The 100-volt range is properly adjusted when the readout display in step 3 is exactly equal to one-tenth of the readout display observed in step 2, (for example: 95.93 in step 2, compared to 9.593 in step 3) and when the error amplifier waveform amplitude and phase are similar to that observed in step 2. If this correspondence is not present, adjust 100-volt range trim potentiometer R4.

Adjusting the 1000-Volt Range Scale Factor

The following procedure is used:

1. Connect the input terminals of a 100-to-1 voltage divider to a stable source of d-c voltage as close to 999 volts as practicable. (Lower voltages, no less than 200 volts, can be used, but accuracy will not be as good as when higher voltages are used.)
2. Connect the input terminals of the voltmeter under test to the input terminals of the voltage divider. Observe the readout display and waveform at the error amplifier test points.
3. Connect the input terminals of the digital voltmeter to the output terminals of the 100-to-1 voltage divider. Observe the readout display and error amplifier waveform.
4. The 1000-volt range is properly adjusted when the readout display in step 3 is exactly one-hundredth of the readout display observed in step 2, (for example: 982.3 in step 2, compared with 9.823 in step 3) and when the error amplifier waveform amplitude and phase are similar to that observed in step 2. If this correspondence is not present, adjust the 1000-volt range trim potentiometer, R2.

PHASE SENSITIVE VOLTMETER, ME-111/U

The ME-111/U voltmeter (fig. 5-29) is designed to measure output voltage, in-phase voltage relative to a reference voltage, and 90° out-of-phase voltage relative to a reference voltage. The main uses of this voltmeter are for observing and correcting phase relationships and for zeroing synchros in gyrocompass systems.

The phase sensitive voltmeter is connected to a system by means of a 5-pin plug and two test jacks, or by the 5-pin plug only. With just the 5-pin plug, there is only one connection for both the reference voltage input and the signal voltage input. When the test jacks and the 5-pin plug are connected to the voltmeter, the test jacks are used for the signal voltage input and the 5-pin plug is used for the reference voltage input. The multiple-connection hookup is preferred since it eliminates the pickup problems which are likely to result with the single-connection hookup where the signal and power leads are near each other.

The reference switch has three positions: scale A, scale B, and total. With this switch in either scale position, you can check the phase relationships of the reference and signal voltages. When the reference switch is in the TOTAL position, the ME-111/U acts as a vacuum tube voltmeter (VTVM) to indicate voltage level irrespective of a reference signal. The voltage range is controlled by the volts selector switch.

CHAPTER 6

SOUND-POWERED TELEPHONES

Telephones provide a rapid and efficient means of communication between the many stations aboard ship. A satisfactory telephone system must be reliable and not susceptible to damage during battle; it must make possible rapid completion of calls; and it must be easy to maintain. The sound-powered telephone fulfills these requirements. As the name implies, the sound-powered telephone requires no outside power supply for its operation. The sound waves produced by the speaker's voice provide the energy necessary for the reproduction of the voice at a remote location.

In addition to sound-powered telephones, some ships are provided with automatic dial-type telephones. The dial telephone system is used for administrative purposes and is not depended upon under battle conditions. The dial telephone system is discussed in chapter 9 of this training manual. This chapter discusses sound-powered telephones and associated circuits and equipment.

Upon completion of this material you should be able to distinguish between the various components of a complete sound powered system. You should further be able to perform maintenance on all circuits in the sound powered group be they switchboard, switchbox, or string.

As an IC Electrician 3 or 2 you will be required to indoctrinate personnel in the uses and capability of the sound-powered system. This chapter will be an aid in that indoctrination.

SOUND-POWERED UNITS

The sound-powered transmitter (microphone) and receiver units in some telephones are identical and interchangeable. Other telephones have sound-powered units that differ physically. The principle of operation, however, is the same for both transmitter and receiver.

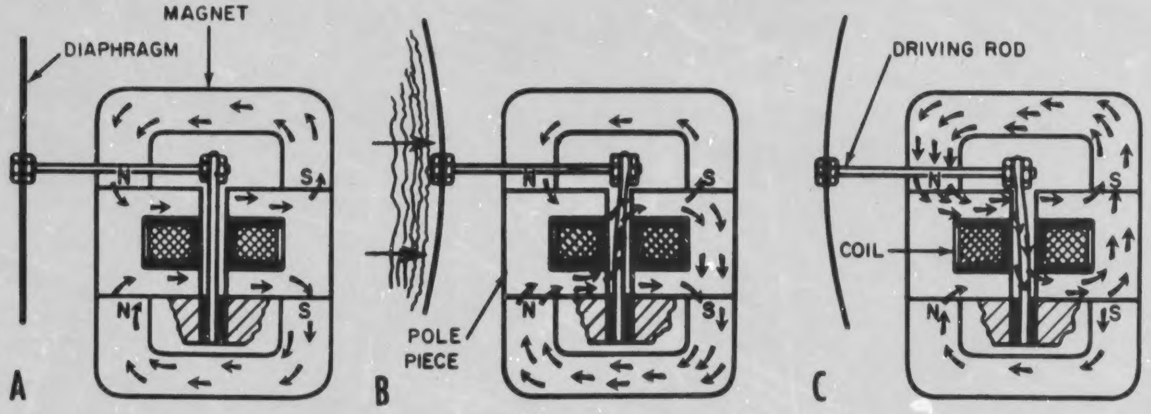
As illustrated in figure 6-1, a unit consists of two permanent magnets, two pole pieces, an armature, a driving rod, a diaphragm, and a coil. The armature is located between four pole tips, one pair at each end of the armature. The spacing between the pole tips at each end is such that an air space remains after the armature is inserted between them. This air space has an intense magnetic field, which is supplied by the two magnets that are held in contact with the pole tips.

The armature is clamped rigidly at one end near one of the pairs of poles and is connected at the other end to the diaphragm by the drive rod. Hence, any movement of the diaphragm causes the free end of the armature to move toward one of the pole pieces. The armature passes through the exact center of a coil of wire that is placed between the pole pieces in the magnetic field.

PRINCIPLES OF OPERATION

Sound waves are compressions and rarefactions of the medium in which they travel. When a diaphragm is placed in the path of a series of sound waves, the waves cause the diaphragm to vibrate. The armature of a transmitter unit, when there are no sound waves striking the diaphragm, is shown in figure 6-1A. Note that the armature is centered between the pole pieces with the magnetic lines of force passing from the north to the south pole and that there are no lines of force passing lengthwise through the armature.

When sound waves strike the diaphragm and cause it to vibrate, the vibrations are impressed upon the armature by means of the drive rod, as shown in figure 6-1B, and C. During the compression part of the wave this action causes the armature to bend and reduce the air gap at the upper south pole. The reduction of the air gap decreases the reluctance between the upper south pole and the armature, while increasing the reluctance between the armature and the upper north pole. This action reduces



27.287

Figure 6-1.—Sound-powered transmitter unit.

the lines of force that travel between the two upper pole pieces. There is no large change in the reluctance at the lower poles; however, the armature has less reluctance than the lower air gap and a large number of magnetic lines of force will follow the armature to the upper south pole. Thus, an emf is induced in the coil by the lines of force that are conducted along the armature and up through the coil.

When the sound wave rarefaction reaches the diaphragm, it recoils, as shown in figure 6-1C, thus causing the armature to bend in the opposite direction. This action reduces the air gap between the armature and the north pole. Note that the reluctance between the armature and upper north pole is decreased and that the lines of force are reestablished through the armature, this time in the opposite direction. Thus, an emf is induced in the coil by the lines of force that are conducted along the armature and down through the coil. This emf is in the opposite direction to that of the emf induced when the lines of force are established, as shown in figure 6-1B.

Sound waves striking the diaphragm cause it to vibrate back and forth. The armature bends first to one side and then to the other, causing an alternating polarizing flux to pass through it, first in one direction and then in the other. These lines of force passing through the armature vary in strength and direction, depending upon the vibrations of the diaphragm. This action induces an emf of varying direction and magnitude—that is, an alternating voltage—in the coil. This alternating voltage has a frequency and waveform similar to the frequency and waveform of the sound wave striking the diaphragm.

When this unit is used as a receiver it operates in a similar manner. The alternating voltage generated in a transmitter unit is impressed upon the receiver coil, which surrounds the armature of the receiver unit (fig. 6-2). The resultant current through the coil magnetizes the armature with alternating polarity. An induced voltage in the coil of the transmitter (fig. 6-2A) causes a current to flow in the coil of the receiver (fig. 6-2B) magnetizing the free end of the armature, arbitrarily with north polarity. The free end of the armature, therefore, is repelled by the north pole and attracted by the south pole. As the direction of the current in the receiver reverses, the polarity of the armature reverses. Thus the position of the armature in the air gap reverses, forcing the diaphragm inward. Hence the diaphragm vibrates in unison with the diaphragm of the transmitter and generates corresponding sound waves.

EQUIPMENT

The two types of sound-powered telephones installed in Navy ships are handsets and headsets. All telephones of a given type are built to the same military specifications regardless of the manufacturer.

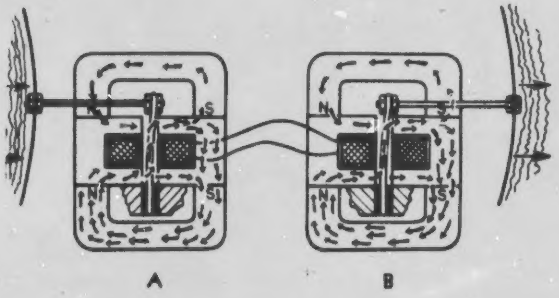


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Figure 6-2.—Operation of sound-powered transmitter and receiver units.

HANDSETS

The type H203/U handset is designed for general use, primarily one-to-one talking. The sound-powered transmitter and receiver units (fig. 6-3) are interchangeable. A nonlocking, normally open, spring return, push switch S1 disconnects the sound-powered units from the line in the open position, and connects the units to the line in the closed (depressed) position. Capacitor C1, is connected in parallel with the sound-powered units for tone compensation.

The type H-204/U handset (not shown) is specially designed for use on a line loaded with other handsets or headsets. The switching arrangement keeps the set off the line when it is not in use. When transmitting, the transmitter unit is across the line and the receiver unit is across the line in series with a 3-db padding resistor. When receiving the receiver unit is directly across the line.

The sound-powered transmitter and receiver units are not interchangeable; however the receiver units are interchangeable with the type H-203/U sound-powered units.

HEADSETS

The type H-200/U headset is designed for general use. The set consists of two sound-powered receiver units with protective shells and ear cushions, one sound-powered transmitter unit with protective shell provided with a push-switch, one mouthpiece, one chest plate assembly with junction box provided with capacitors and terminal facilities, one headband assembly and neck strap, and one cord assembly and plug. The receivers are mounted on the headband; the transmitter on the chest plate. Closing the press-to-talk switch S1, (fig. 6-4), connects the sound-powered transmitter unit across the line. The receiver units are permanently connected across the line when the set is plugged in.

When a sound-powered telephone set is used on the output side of a sound-powered telephone amplifier, a small d-c voltage is placed across the set. The purpose is to provide an amplifier squelching circuit to avoid acoustical feedback when the local set is transmitting. Capacitor C1 (fig. 6-4), blocks the d-c from the receiver units. The press-to-talk switch allows the d-c to flow when transmitting, and operates a sensitive switch in the amplifier. The two capacitors are in series across the line. The sound-powered

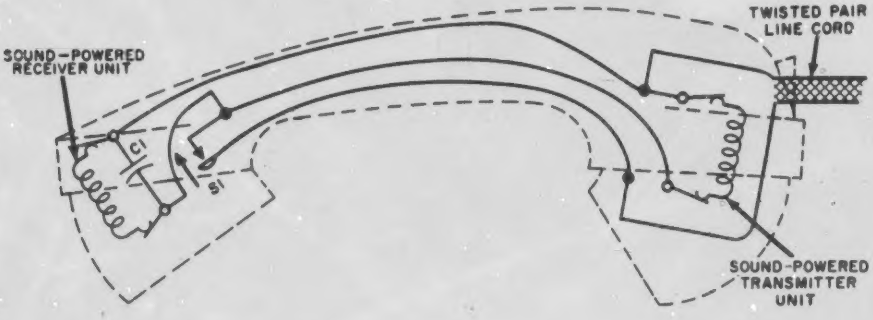

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Figure 6-3.—Sound-powered telephone handset wiring diagram.

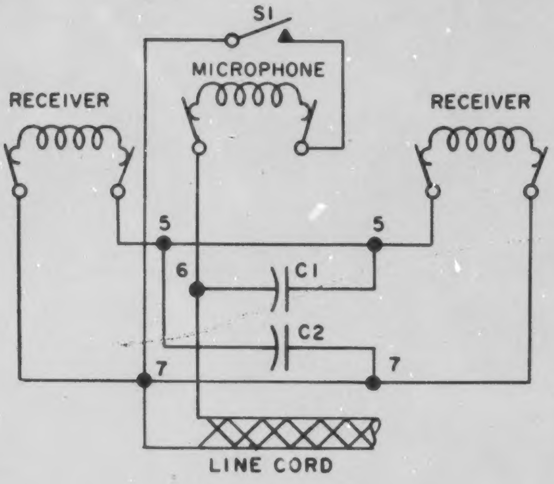

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Figure 6-4.—Sound-powered telephone headset type H-200/U wiring diagram.

transmitter and receiver units are not interchangeable.

The type H-201/U headset (not shown) is a specially designed set for use by plotters, console operators, etc. The transmitter is suspended from the headband by a boom. The boom may be adjusted to place the transmitter in front of the wearer's mouth. The junction box with terminal facilities, capacitors, and the normally open, spring return, push switch, is fitted with a clip that allows it to be attached to the wearer's belt. The sound-powered units are not interchangeable.

The type H-202/U headset is a specially designed set for use in areas having high noise levels. The receiver units are housed in noise attenuating shells consisting of plastic caps lined with sound absorbing material. The sound-powered units are not interchangeable.

HANDLING AND STOWAGE

The connecting wires secured to the various portions of telephone sets have but one purpose—to transmit electric current. They are not provided as straps for supporting the equipment nor should they be subjected to a jerk or fall. When a plug is removed from a jack, the BODY of the plug should be pulled—never the CORD. Connections should be made so that a minimum of physical strain is put on the electric conductors. If the talker must remove the telephone set from his head, he should hang the set by the head band and the neck strap—not by any of the connecting wires. Figure 6-5 shows a properly made up headset and several properly stowed sets.

The unit is made as waterproof as possible, but it should not be exposed unnecessarily to the weather. Moisture and good telephone service do not go hand-in-hand. Remember that several conductors, which actually carry the messages to and from the telephone, lie underneath the rubber covering on the various electric cords on the set. Although these cords are quite flexible, they should not be dragged over sharp edges, pulled too hard, or allowed to kink. The cords are especially susceptible to damage because of their small size. If you instruct other men on how to handle telephones, emphasize the importance of handling the set with care so that the set will not be out of order in an emergency.

Telephone headsets used in exposed areas are stowed in boxes located on weather decks. Those sets used in protected areas are stowed on bulkhead hooks located in various compartments. The set must be made up properly for either means of stowage. Use the following procedure to make up a sound-powered telephone headset for stowage.

1. Remove the headband and hang the headband over the yoke of the transmitter.
2. Remove the phone jack and secure the jack box cover to keep out moisture and dirt. Lay the line out on the deck and remove any kinks. Begin coiling from the end that attaches to the chest plate. Coil the line with the right hand, making the loops in a clockwise direction. The loops should be about 10 inches across.
3. When the lead is coiled, remove the ear pieces from the transmitter yoke and hold the headband in the same hand with the coil.
4. Fold the transmitter yoke flat so that the transmitter mouth piece lays flush against the breast plate connection box, using care not to pinch the transmitter cord.
5. Holding the headband and coil in the left hand, unhook one end of the neck strap from the chest plate.
6. Bring the top of the chest plate level with the coil and headband. Secure the chest plate in this position by winding the neck strap around the coil and headband just enough times so that there will be a short end left over. Twist this end once and refasten it to the chest plate. The headset is then made up in a neat package ready

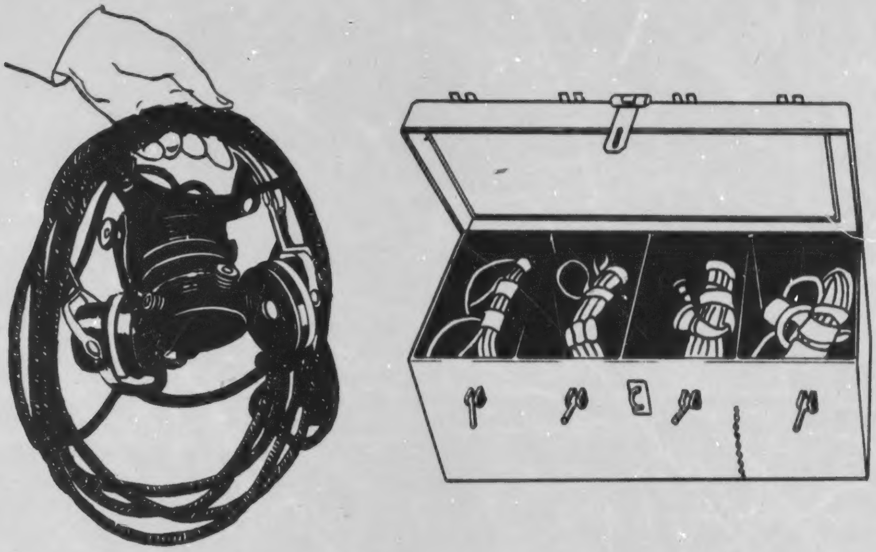

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Figure 6-5.—Properly made up and stowed headset.

for stowing. A set properly made up fits into its stowage box without forcing. Never allow loose cord to hang out of the box because it may be damaged when the lid is closed.

Stow only battle telephones in telephone stowage boxes—never put cleaning gear or tools in these boxes. Rags give off moisture, which may ruin the phone, and soap powder gives off fumes that rapidly oxidize the aluminum diaphragm. Tools and other loose gear may prevent getting the phone out quickly, or may damage the phone.

Sound-powered handsets are fastened to a connection box by a coiled cord. A stowage hook, or handset holder, is provided for each handset, and the set must be properly replaced in the holder at all times when not actually in use. A handset left in the bottom of the holder provides an excellent lever for breakage. No special care, other than intelligent handling, is needed for handsets as they are much less subject to trouble than are headsets.

REPAIRS

As an IC Electrician, you will be required to service sound-powered telephones. Because a great deal of time is devoted to the repair of these sets, you should be thoroughly familar with the proper methods of testing and repairing them. Many of the larger ships have a telephone shop that is devoted entirely to the repair of sound-powered telephones.

When trouble develops in a sound-powered headset, the usual procedure followed by the talker is to exchange it for a good one at the repair shop. This procedure provides each station with properly operating sets at all times and concentrates the repair of these sets in one location. The shop maintains a log of all sets turned in and the station from which they are received. This practice aids in locating faulty circuits or talkers who continually abuse their sets.

Inspection

A routine inspection of sets should be made before repairs are begun to determine whether physically defective parts should be replaced. Many troubles may be located by inspecting the set for damaged cord or insulation; cords pulled out of units; loose units; defective or broken pushbuttons; and broken or damaged parts, such as unit covers, neck strap, chest plate, junction box, plug, and headband.

Precautions

In repairing sound-powered telephones observe the following precautions:

- Do not repair telephones on a dirty workbench. The magnets in the units may attract iron fillings, which are difficult to remove.
- Never alter the internal wiring of sets.
- Before disassembling a unit, make a wiring diagram showing the color coding, polarity, or terminal numbers of the lead connections.
- Always replace parts exactly as they were before disassembly.

Open and Short Circuits

Use a low voltage ohmmeter to test for opens and shorts to avoid damage to the sound-powered units. Continuity tests may be made from the chest plate junction box on the types H-200/U, and H-202/U headsets. The normal d-c resistances of the sound-powered transmitter and receiver units are 10 ohms and 62 ohms respectively. A short circuit in a single unit renders an entire telephone circuit inoperative because it parallels all of the other units.

Loss of Sensitivity

Loss of sensitivity, or weakening of the transmission sound, is a gradual process and seldom is reported until the set becomes practically inoperative. When a sound-powered telephone is in good condition electrically yet the sound is weak, the transmitter unit should be replaced. If this procedure does not remedy the trouble, the receiver units should be replaced.

Headsets may be tested for loss of sensitivity by depressing the talk switch, and blowing into the transmitter. If the set is operating properly, a hissing noise is heard in the receiver units caused by the air striking the transmitter. One receiver unit is listened to, and then the other. In most cases, the loss in sensitivity is in the transmitter unit and might be caused by a displacement of the armature from the exact center of the air gap between the pole pieces.

Each sound-powered handset is tested on location because it is connected permanently to a box. The simplest test is to blow air into the transmitter. To test each individual handset it is not necessary to press the talk button because the transmitter and receiver are permanently connected in parallel. If no sound is heard, either the transmitter or the receiver is defective. The easiest method to determine whether the transmitter or the receiver is defective is to have someone talk into another phone on the line and to listen to both the transmitter and the receiver of the handset. If the talker's voice is heard on one of the units but not the other, the unit on which the voice is not heard is the defective one and should be replaced. If the talker's voice cannot be heard on either unit, and the telephone circuit being used for the test is known to be free of trouble, the fault may be traced to the line cord, switch, or internal handset circuits.

Replacing Cords

When it is necessary to replace a defective cord between the junction box and the transmitter or receivers of headsets, tinsel cord should be used. Stocks of tinsel cord cut to the proper lengths for use with the various types of headsets and fitted with terminals are stocked at supply depots and should be requisitioned for use. Bulk tinsel cordage is also stocked at supply depots as standard stock. Always use prepared cords if possible.

If prepared cords are not available, you can make them from bulk tinsel cord by the following procedure:

1. Strip about 2 in. of the outer layer of insulation from one end of the cord.
2. Remove about one-fourth of an inch of insulation from the ends of the conductors, exercising caution not to damage the tinsel wire.
3. Wind a single layer of 32-gage tinned copper wire over the tinsel wire and extend the tinned copper wire about one-eighth of an inch over the rubber insulation.
4. Dip these whipped conductors into melted solder and flatten them slightly when cool.
5. Solder the whipped conductor to a lug or cord tip as required (fig. 6-6).

If tinsel cord is not available, use standard DCP-1/2 cord between the junction box and the receivers and transmitter. Use DCOP 1 1/2 cord between the junction box and the plug.

To replace a cord:

1. Open each unit connected to the cord that is to be replaced.

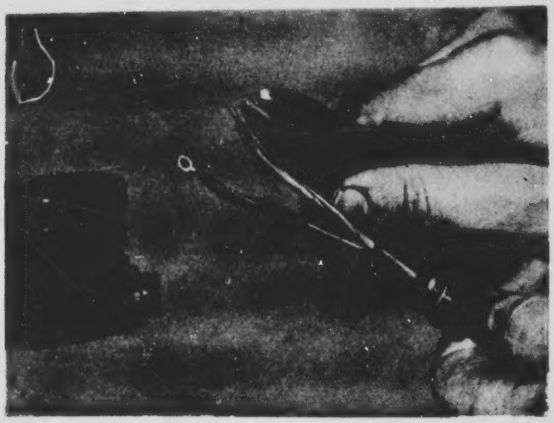

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Figure 6-6.—Preparing a new tip on a tinsel cord.

2. Before disconnecting the cord make a diagram showing the color coding of the wires.

3. Disconnect both ends of the cord.

4. Remove the screw that holds the tie cord or untie the cord if it is secured to an eyelet.

5. Unscrew the entrance bushing, if provided, and pull the cord through the port.

6. Place the threaded entrance bushing, metal washer, and rubber gasket on the new cord and insert the cord into the entrance port (fig. 6-6). The cord should be long enough to allow slack after it is connected.

7. Secure the tie cord so that it takes all the strain off the connections; otherwise the wires might be pulled from their terminals.

8. Connect the wires to their terminals.

9. Screw the entrance bushing on the entrance port, drawing the bushing up tightly to secure the cable and to seal the port.

10. Close the unit after all connections have been visually checked.

11. Test the completed unit for operation.

SOUND-POWERED TELEPHONE SYSTEMS

There are three types of sound-powered telephone systems:

1. The primary battle telephone system-circuits JA to JZ (table 6-1)—includes all circuits used for the main channels of communications in controlling the armament, engineering, damage control, and maneuvering of a typical CVA.

2. The auxiliary battle telephone system—circuits XJA to XJZ—includes circuits duplicating certain primary battle telephone circuits as alternates in case of damage. The wiring of the auxiliary circuits is separated as much as practicable from the wiring of the corresponding primary circuits to prevent battle damage to both circuits.

3. The supplementary telephone circuits X1J through X61J, consists of a group of outlets connected together on a single line or "string," with no provision for cutting out a single outlet. A supplementary circuit may be one that is required for use at all times or at times when battle telephones are not manned. Some "string" circuits are equipped with call-bell systems.

The various sound-powered telephone systems are classified further into switchboard circuits, switch-box circuits, and string-type circuits.

SWITCHBOARD CIRCUIT

A switchboard circuit is a circuit having cutout switches on a sound-powered telephone switchboard. (Table 6-2 is a glossary of terms for telephone switchboards and circuits.) Most large combatant ships have several sound-powered telephone switchboards installed in different centrally located and protected control stations, such as IC rooms and plotting rooms. Smaller combatant ships usually have only one sound-powered telephone switchboard; it is normally located in the IC room. Each switchboard (fig. 6-7) usually has several switchboard circuits and a line-disconnect switch for each line. The older type (fig. 6-7A) is replaced with the newer switchboard (fig. 6-7B) which has a switchjack (fig. 6-7C) at each position. The switchjack consists of a line switch and jack. The purpose of the line switch is either to connect or disconnect a station from its circuit. The jack either parallels that phone with another circuit or parallels two circuits. Paralleling is accomplished by means of a PATCHING CORD, which is a short length of portable cord having a jack plug at each end. Primary and auxiliary circuits can be connected either through the switchboard or through switchboxes located at the controlling station for each circuit. On smaller ships only the most vital primary circuits are backed up by auxiliary circuits. When an auxiliary circuit is controlled

Table 6-1.—Sound-Powered Telephone Circuits

Circuit	Primary Circuits Title
JA	Captain's battle circuit
JC	Weapons control circuit
10JC	Missile battery control circuit
JD	Target detectors circuit
JF	Flag officer's circuit
1JG	Aircraft control circuit
2JG	Aircraft information circuit
2JG1	Aircraft strike coordination circuit
2JG2	Aircraft strike requirement and reporting circuit
2JG3	Aircraft information circuit CATTC direct line
3JG	Aircraft service circuit
4JG1	Aviation fuel and vehicular control circuit
4JG2	Aviation fueling circuit forward
4JG3	Aviation fueling circuit aft
5JG1	Aviation ordnance circuit
5JG2	Aviation missile circuit
6JG	Arresting gear and barricade control circuit
9JG	Aircraft handling circuit
10JG	Airborne aircraft information circuit
11JG	Optical landing system control circuit
JH	Switchboard cross connecting circuit
JL	Lookouts circuit
JK	Double purpose fuse circuit
JM	Mine control circuit
JN	Illumination control circuit
JO	Switchboard operators' circuit
2JP	Dual purpose battery control circuit
4JP	Heavy machine gun control circuit
5JP	Light machine gun control circuit
6JP	Torpedo control circuit
8JP	ASW weapon control circuit
9JP	Rocket battery control circuit
10JP	Guided missile launcher control circuit

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Table 6-1.—Sound-Powered Telephone Circuits—Continued

	Primary Circuits
Circuit	Title
10JP1	Starboard launcher circuit
10JP2	Port launcher circuit
11JP	FBM checkout and control circuit
JQ	Double purpose sight setters circuit
JR	Debarkation control circuit
JS	Plotters' transfer switchboard circuit
1JS	CIC information circuit
2JS	NTDS coordinating circuit No. 1
3JS	NTDS coordinating circuit No. 2
20JS1	Evaluated radar information circuit
20JS2	Evaluator's circuit
20JS3	Radar control officer's circuit
20JS4	Weapons liaison officer's circuit
21JS	Surface search radar circuit
22JS	Long range air search radar circuit
23JS	Medium range air search radar circuit
24JS	Range height finder radar circuit
25JS	AEW radar circuit
26JS	Radar information circuit
31JS	Track analyzer No. 1 air radar information check
32JS	Track analyzer No. 2 air radar information check
33JS	Track analyzer No. 3 air radar information check
34JS	Track analyzer No. 4 air radar information check
35JS	Raid air radar information circuit
36JS	Combat air patrol air radar information circuit
61JS	Sonar information circuit
80JS	ECM plotters' circuit
81JS	ECM information circuit
82JS	Supplementary radio circuit
JT	Target designation control circuit
1JV	Maneuvering and docking circuit
2JV	Engineers' circuit (engines)

27.337.2

Table 6-1.—Sound-Powered Telephone Circuits—Continued

Circuit	Title
	Primary Circuits
3JV	Engineer's circuit (boiler)
4JV	Engineer's circuit (fuel and stability)
5JV	Engineer's circuit (electrical)
6JV	Ballast control circuit
11JV	Waste control circuit
JW	Ship control bearing circuit
JX	Radio and signals circuit
2JZ	Damage and stability control
3JZ	Main deck repair circuit
4JZ	Forward repair circuit
5JZ	After repair circuit
6JZ	Midships repair circuit
7JZ	Engineer's repair circuit
8JZ	Flight deck repair circuit
9JZ	Magazine sprinkling and ordnance repair circuit forward
10JZ	Magazine sprinkling and ordnance repair circuit aft
11JZ	Gallery deck and island repair circuit
	Auxiliary Circuits
XJA	Auxiliary captain's battle circuit
X1JG	Auxiliary aircraft control circuit
X1JV	Auxiliary maneuvering and docking circuit
XJX	Auxiliary radio and signals circuit
X2JZ	Auxiliary damage and stability control circuit
	Supplementary Circuits
X1J	Ship administration circuit
X2J	Leadsman and anchor control circuit
X3J	Engineer watch officer's circuit
X4J	Degaussing control circuit
X5J	Machinery room control circuit
X6J1	Electronic service circuit
X6J7	ECM service circuit
X6J11-14	NTDS service circuits
X7J	Radio-sonde information circuit

27.337.3

Table 6-1.—Sound-Powered Telephone Circuits—Continued

	Supplementary Circuits
Circuit	Title
X8J	Replenishment-at-sea circuit
X9J	Radar trainer circuit
X10J	Cargo transfer control circuit
X10J1	Cargo transfer circuit-Lower decks
X10J10	Cargo transfer circuit-Upper decks
X11J	Captain's and admiral's cruising circuit
X12J	Capstan control circuits
X13J	Aircraft crane control circuits
X14J	Missile handling and nuclear trunk crane circuit
X15J	SINS information circuit
X16J	Aircraft elevator circuit
X17J	5-inch ammunition hoist circuit
X18J	Machine gun ammunition hoist circuits
X19J	Missile component elevator circuit
X20J	Weapons elevator circuits
X21J	Catapult circuit
X22J	Catapult steam control circuit
X23J	Stores conveyor circuit
X24J	Cargo elevator circuit
X25J	Sonar service circuit
X26J	Jet engine test circuit
X28J	Dumbwaiter circuit
X29J	Timing and recording circuit
X34J	Alignment cart service circuit
X40J	Casualty communication circuit
X41J	Special weapons shop service circuit
X42J	Missile assembly and handling circuit
X43J	Weapons system service circuit
X44J	ASROC service circuit
X45J	Special weapons security circuit
X50J	Fog foam circuit
X61J	Nuclear support facilities operations and handling circuit

27.337.4

Table 6-2. —Sound-Powered Telephone Systems Glossary

GLOSSARY

BUS--The common connection between a group of line cutout switches. It may be in a single section or divided; it may be connected to a jack outlet or be free.

BUS TIE SWITCH--A switch connecting separate parts of the same circuit or similar circuits on a switchboard or switchbox.

PLOTTERS' TRANSFER SWITCHBOARD--A radio-type transfer switchboard performing the function of selector switches.

SELECTOR SWITCH--A switch connecting one of several lines to a single jack outlet.

TIE LINE--A line between two switchboards, two switchboxes, or a switchboard and a switchbox. It connects two circuits and is terminated by a switch at each end.

TIE PLUS SWITCH--A normally closed switch at the opposite end of a tie line from the tie switch. It may be opened to clear a damaged circuit.

TIE SWITCH--A switch at one end of a tie line, usually the end connected to an auxiliary circuit. It is normally open unless the ship's doctrine requires that it be closed.

TRANSFER SWITCH--A switch for connecting the lines of one circuit group to one of several other circuit groups.

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through a switchbox, the circuits can be cross-connected to the primary circuits on the main board by means of a tie line.

SWITCHBOX CIRCUIT

A switchbox circuit consists of several line cutout switches mounted in a switchbox. Usually, there is only one switchbox for each circuit. Telephone switchboxes function primarily as small ACO switchboards. The switchboxes are located at the principal station on the circuit, and contain either 10 or 20 switches used for connecting incoming lines to a common circuit bus (fig. 6-8). Each station on the circuit is connected to one of the line switches. Some of the switches may be used as tie switches connected to the circuit bus in other switchboxes. When these tie switches are closed, the circuits in the two boxes are paralleled.

All primary circuits are provided with a tie line for cross connection with their auxiliary circuits. The tie lines are fitted with a tie switch at one end and a tie + (tie plus) switch at the other end. The tie + switch is different from the tie switch only in that the tie + switch is always closed to ensure that the tie line may be used at all times. With this arrangement the two circuits can be tied together or separated by closing or opening the tie switch. In case of a casualty to

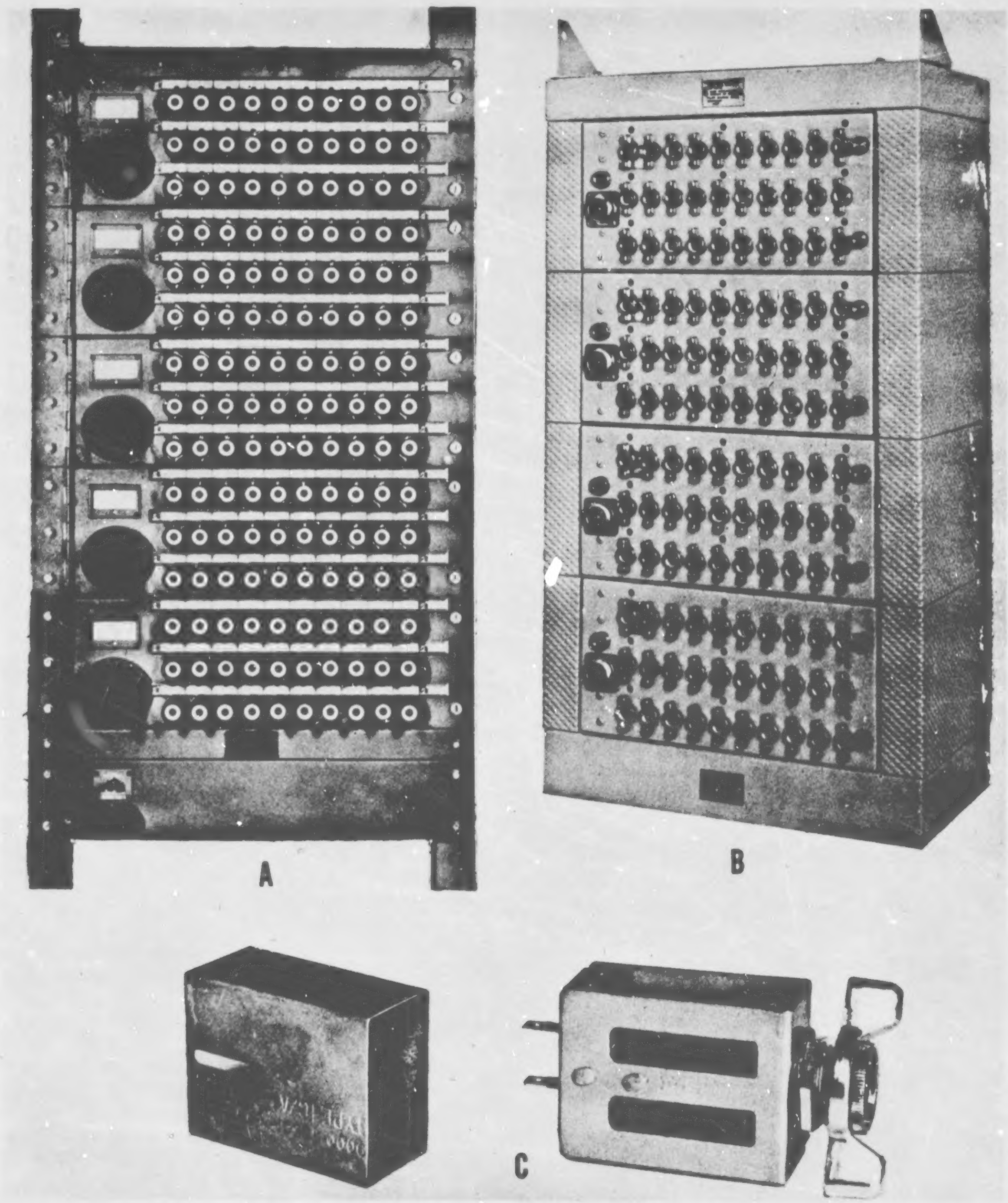

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Figure 6-7.—Sound-powered switchboards.

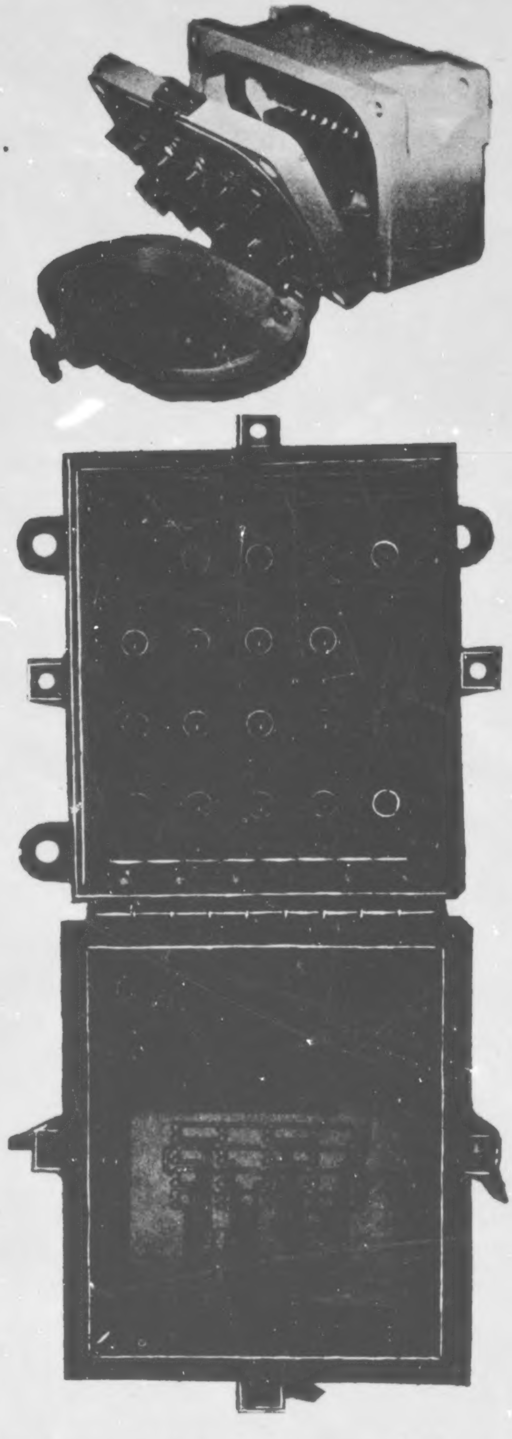


Figure 6-8.—A.C.O. switchboxes. Top new; bottom old. 27.291X

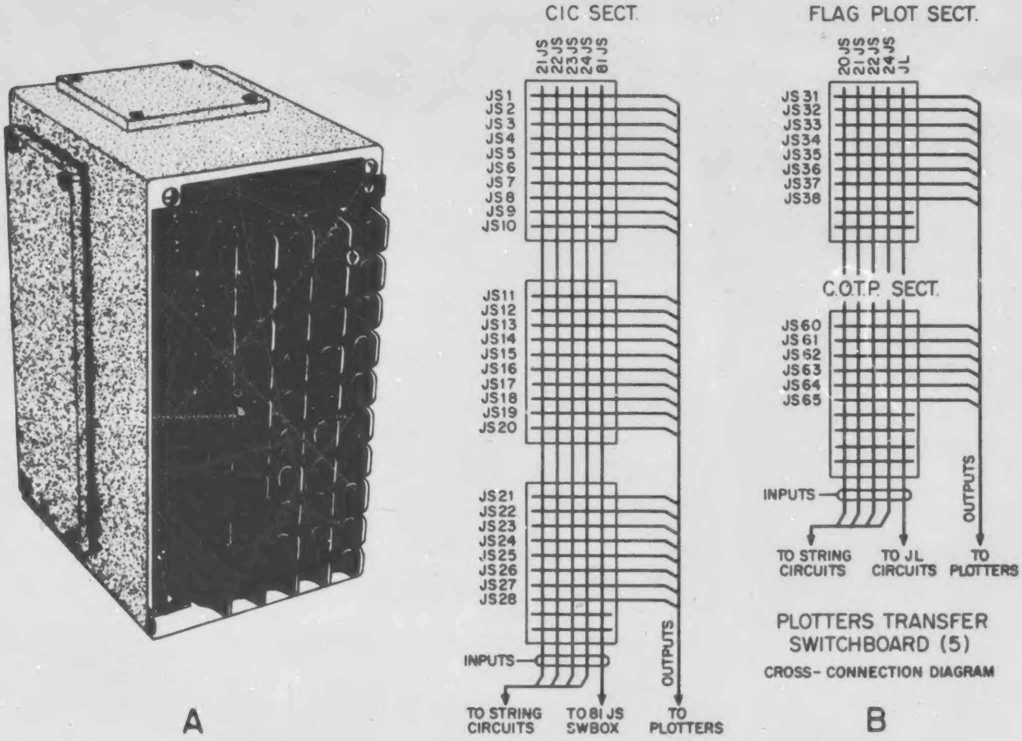
the tie switch end of the tie line the tie + switch is opened to disconnect the defective circuit or tie line.

Connecting Primary and Auxiliary Circuits

A ship's sound-powered telephone system is designed so that there are backup circuits for all vital circuits. On large combatant ships, many primary circuits are paralleled by auxiliary circuits; on other ships, only a few. However, all important stations aboard ship are served by more than one primary circuit.

Auxiliary circuits are normally connected to their primary circuits when all tie switches on the auxiliary switchboard are left closed. Connecting or tying of circuits results in paralleling as many headsets as there are manned stations. In an extensive telephone system, paralleling of circuits has both advantages and disadvantages. One advantage is that it allows a controlling station to extend supervision over many stations, using fewer talkers. Also, if communications is lost to one of the primary stations, paralleling enables the talker at the station to re-establish easily communications with the control station by pulling the plug of his headset from the primary jackbox and inserting the plug into the auxiliary jackbox. However, paralleling all the auxiliary lines with the primary lines makes it harder to locate and isolate a casualty that results in loss of contact or reduced sound caused by too much of the transmitted energy being dissipated. There is another disadvantage to paralleling circuits where some tie switches are located on switchboards and some in rather inaccessible switchboxes. In this case, the control station operator may have trouble locating the proper tie switches when required to separate the circuits quickly or to change the setup.

An increase in the number of paralleled circuits tends to make the system more troublesome and to lower its traffic-handling capacity. More paralleled circuits could mean more repeats and garbles, overloaded transmitters, and more difficulty in locating and clearing faulty circuits. The problems are not too severe if all equipment is in good condition and operators use proper techniques. Because of the advantages and disadvantages, the doctrine of closing all tie switches may be best for some circuits, but not all. Your ship's doctrine will determine whether the switches are to be kept closed or open.


CIC SECT.
21JS
22JS
23JS
24JS
81JS
JS1
JS2
JS3
JS4
JS5
JS6
JS7
JS8
JS9
JS10
JS11
JS12
JS13
JS14
JS15
JS16
JS17
JS18
JS19
JS20
JS21
JS22
JS23
JS24
JS25
JS26
JS27
JS28
INPUTS
OUTPUTS
TO STRING CIRCUITS
TO 81 JS SWBOX
TO PLOTTERS
FLAG PLOT SECT.
20JS
21JS
22JS
24JS
JL
JS31
JS32
JS33
JS34
JS35
JS36
JS37
JS38
C.O.T.P. SECT.
JS60
JS61
JS62
JS63
JS64
JS65
INPUTS
OUTPUTS
TO STRING CIRCUITS
TO JL CIRCUITS
TO PLOTTERS
PLOTTERS TRANSFER SWITCHBOARD (5)
CROSS-CONNECTION DIAGRAM
A
B

36.69

Figure 6-9.—Plotters transfer switchboard, type SB-82/SRR. (A) External view; (B) Wiring diagram.

Circuits may also be parallel with the communication consoles in CIC. Telephone circuits may be connected in multiple by operation of the paralleling switches on each console. Since each circuit is routed to a number of plotters' positions, care must be taken to avoid overloading the transmitter.

STRING TYPE CIRCUIT

A string type circuit consists of a series of jack boxes connected in parallel to a single line. There are no action cutout switches for individual stations. However, some string circuits (21JS to 24JS) are connected to communication consoles, selector switches, and plotter transfer switchboards (fig. 6-9).

Some string type circuits, such as X1J Captains and Admirals cruising, may be equipped with call bells, annunciators, or magneto call stations.

SELECTOR AND TRANSFER SWITCHES

Selector and transfer switches are of the rotary type. Selector switches are located in the most important stations throughout the ship to enable the officer in charge, or his talker, to connect his telephone at will to any one of a group of circuits without having to change from one jack outlet to another.

Transfer switches are usually installed at the telephone switchboards and are used to connect the lines of one group of circuits to one of several other groups of circuits.

Circuit Connections Under Conditions of Readiness

Under normal operating conditions, telephone circuits are usually paralleled to reduce the number of talkers required since a relatively small amount of traffic is carried on any one circuit. A talker on the bridge can be connected with main control and after steering through the 1JV circuit, with the lookouts through the JL circuit, with CIC through the 1JS circuit, and with sonar through the 61JS circuit. As conditions of greater readiness are set, more talkers are assigned to the bridge and fewer circuits are paralleled. Few, if any, primary circuits are cross-connected under the highest condition of readiness.

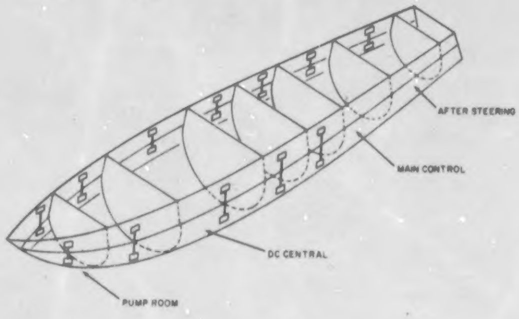
Circuit Connections for Casualty Control

It is most important to have fast and reliable internal communications when a ship is being damaged. In case of extensive damage, considerable cross-connecting and patching may be required to restore an effective degree of internal communications. You must be ready to apply your ship's doctrine for casualty control of the sound-powered telephone system.

Damaged lines must always be cut out until repaired. A cut or damaged line may short and interrupt an entire circuit. If a compartment is abandoned because of fire or flooding, you must isolate all telephone lines in the space by cutting them out at the switchboard and switchboxes.

When a telephone line to one talker is damaged, it is cut out at the IC switchboard. Communications with the talker can be restored by patching from his circuit to a workable line having a jackbox near his station. If a usable line having an outlet by the station is found, the talker will plug into its outelt. If the line to be patched in is on an auxiliary circuit, the switch to the new line is closed at the auxiliary switchbox. The tie line between the switchbox and the damaged line is cut out at the IC switchboard. The talker is now back on his circuit, using an auxiliary line.

You can substitute a line in another primary circuit for a damaged line by patching at the IC switchboard. With old switchboards, you parallel two primary circuits by using the transfer switch. With new boards having switch jacks for each line, you connect a line into another circuit. As an example, assume that the JL line to the starboard wing of the bridge is damaged, but there is still a workable outlet on the 1JV circuit at the station. You disconnect the 1JV line from the rest of the 1JV circuit by using the switch jack. You disconnect the damaged JL line with the switch jack, so it will not interfere with the rest of the JL circuit. Run a patch cord between a "live" jack on the JL part of the board, and the jack on the 1JV circuit that you are going to use. That line is now a part of the JL circuit; when the bridge talker plugs into it, he is back in communication.



140.187
Figure 6-10.—X40J circuit risers.

CIRCUIT X40J—CASUALTY COMMUNICATIONS

Circuit X40J is a means of emergency communications between the bridge, central control station, IC rooms, machinery rooms, and steering gear rooms in case extensive casualties disable normal communications. Installation of the circuit will vary from ship to ship. Aboard one ship, circuit X40J is made up of (1) permanently installed risers (fig. 6-10) from major control spaces below the waterline to scattered main deck locations and (2) portable patch cables which may be plugged into the permanent outlets in any combination required by the extent of damage to the regular sound-powered telephone system. The portable patch cables, each 200 feet long, and portable double jackboxes are stored in each repair party locker. The cables are equipped with telephone jack plugs at each end; the jackboxes are used to couple lengths of the cable, as necessary.

HIGHLINE CIRCUITS

The IC Electricians are responsible for maintaining the sound-powered telephone portion of the bridge-to-bridge phone/distance line and the station-to-station phone lines. During transfer at sea, ships communicate over the bridge-to-bridge line. The station-to-station line is used for communications between each delivery and receiving ship transfer station. Each line is at least 350 feet long, being made of 1 1/2-inch-circumference, 3-strand, lightweight, polypropylene. Each strand of the line has one wire interwoven in it. Both lines have identical sound-powered telephone connections. Double-gang jack boxes are attached to both ends of each line; the boxes are labeled either BRIDGE-TO-BRIDGE phone or STA.-TO-STA. phone.

The bridge-to-bridge phone/distance line is made up by the ship's deck division. Distance markers are attached to this line at 20-foot intervals. These markers consists of colored cloth squares for daytime use and red flashlights for nighttime use. Except for the markers which it doesn't have, the station-to-station line is identical to the bridge-to-bridge line. After a new line is made up, the IC gang installs the jack boxes and makes the sound-powered telephone connections. These connections must be as secure as possible since the line is handled roughly.

MAINTENANCE

Preventive maintenance for sound-powered telephone circuits consists of routine tests and inspections, and cleaning. All circuits should be tested at least weekly to ensure that they are working properly. Cleanliness is essential to the proper operation of sound-powered telephone switchboards due to the low voltages and currents involved. Dirt and dust between closely spaced contacts can cause cross-talk. Use a portable blower or vacuum cleaner to clean switchboards and switchboxes at least monthly.

Insulation tests should be made periodically on all sound-powered telephone cables. In testing insulation, keep all line switches closed and all tie switches between circuits open. The pushbuttons on handsets must be open. Unplug the headsets and remove the sound-powered telephone amplifiers from their cases.

A separate insulation test should be made for each circuit. Measure the resistance between each conductor and ground, and between each pair of conductors.

The minimum allowable insulation resistance reading depends upon the length and temperature of the cable. Lengthy cable runs on large ships may read as low as 50,000 ohms and be satisfactory.

CALL-BELL SYSTEMS

Call-bell systems provide a means of signaling between stations in a ship. These systems consist of circuits E and A.

CIRCUIT E

Circuit E provides a means of signaling between stations on sound-powered telephone circuits and between outlets on voice tubes. In large ships this circuit may be designated as follows:

EM—Self-contained circuits with magneto call-bells. Stations at all calling and some receiving stations provide for selective calls over common talk circuits.

MJ—Self-contained circuits with magneto call-bells. Stations at all calling and some receiving stations provide for selective calls over selective talk circuits.

EP—Protected call circuits with cable runs protected behind armor.

EPS—Unprotected signal lines supplied from an EP circuit through separate protected fuses at the calling station.

EPL—Unprotected circuits supplied from an EP circuit through a protected local cut-out switch at the station called.

EX—Exposed call circuits with cable runs not protected behind armor.

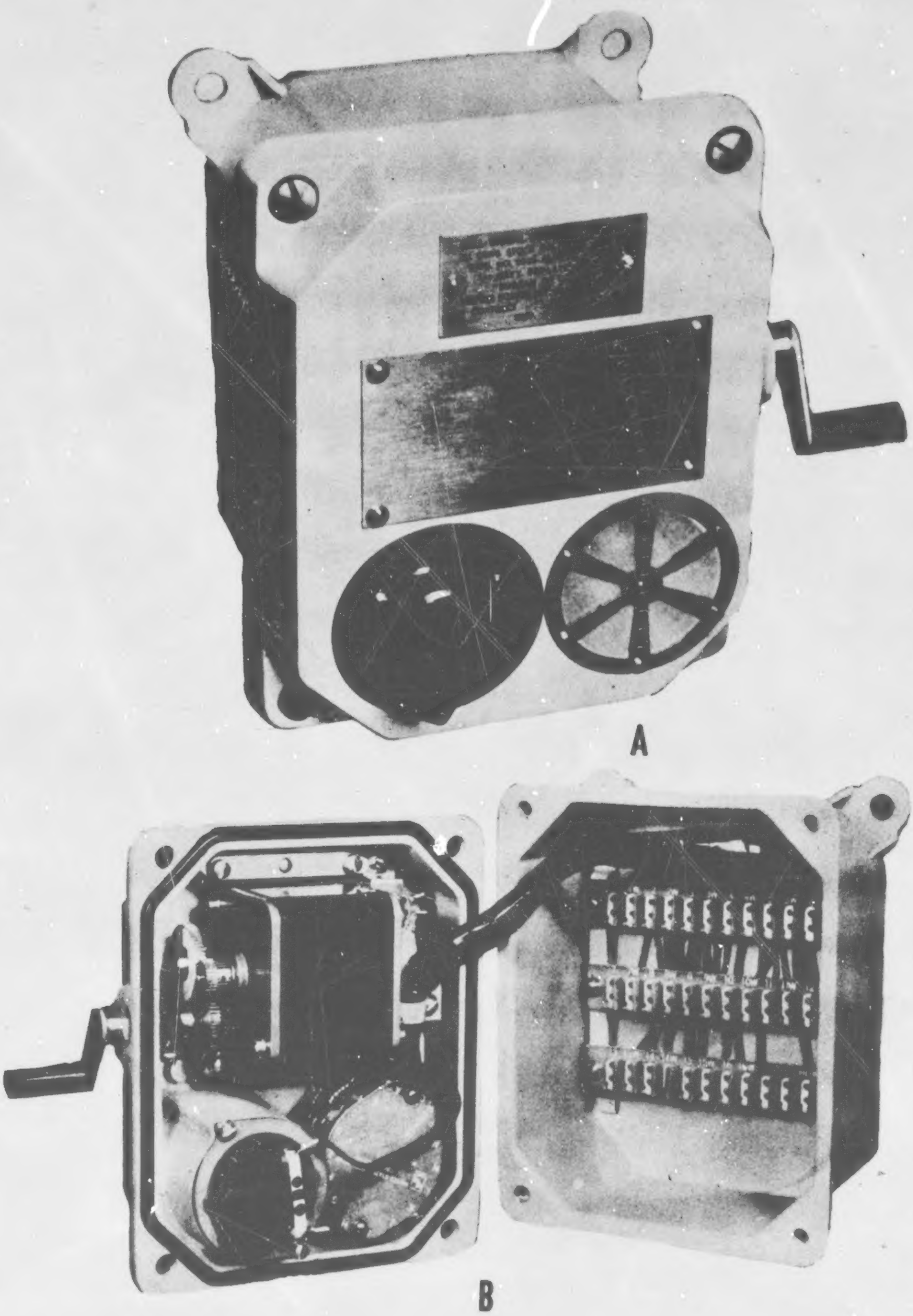
In addition, circuit E has the following functional designations:

1E—Cruising and miscellaneous.
2E—Ship control.
3E—Engineering.
4E—Aircraft control.
5E—Fire control.
11E through 15E—Turrets I through V.

For example, a circuit that is designated as 3EP is an engineering call-bell circuit with cables protected behind armor.

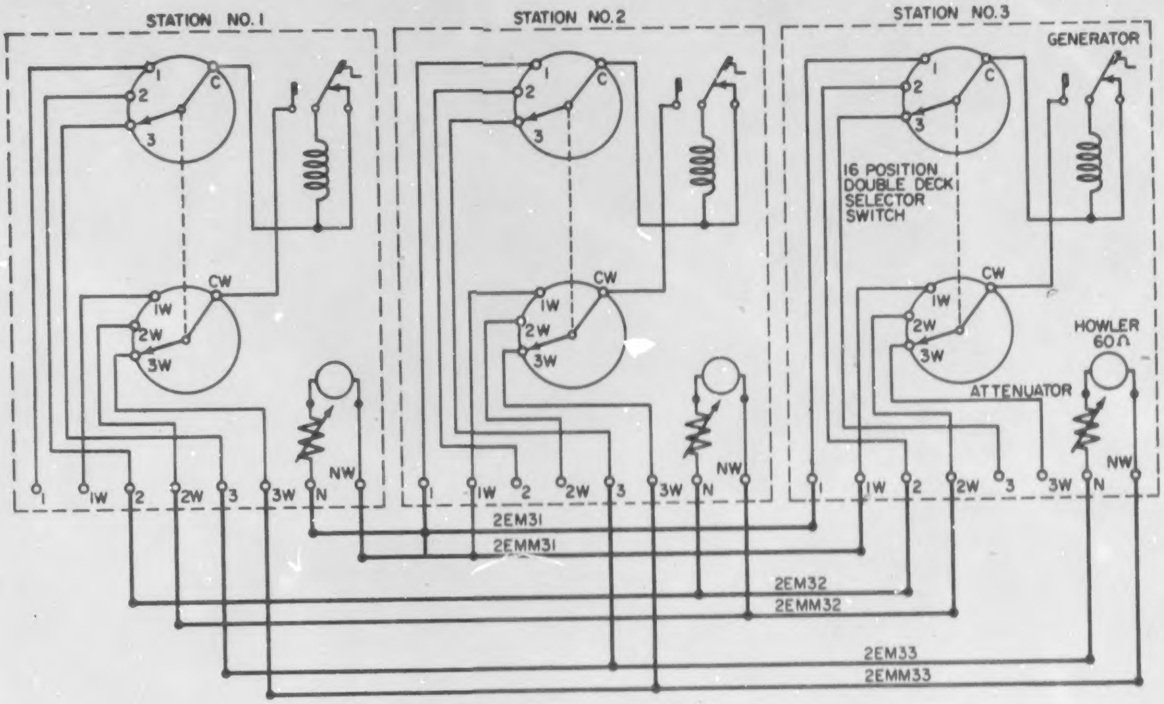
Circuit E includes bells, buzzers, or horns installed at selected sound-powered telephone stations and at some voice tubes. Watertight and nonwatertight pushbuttons, or turn switches, are provided at all signaling stations to complete circuits to the station called. Annunciators are installed at stations where several circuits have outlets.

The EM and MJ circuits may have as many as 16 ringing stations (fig. 6-11). These stations



74.66X

Figure 6-11.—Magneto ringing station. (A) External view; (B) Internal view.



140.35

Figure 6-12.—Sound-powered magneto call system.

are of cast aluminum with all of the equipment on the cover, except for the terminal board for the connections. Assembled on the cover are the rotary selector switch, a hand-operated magneto generator, a howler unit, and an attenuator to control the volume of the howler. The telephone circuit may be of the string or switchboard type.

The operator simply turns the selector switch to the station to be called and cranks the generator handle. The howler (a modified sound-powered telephone receiver unit at the selected station) will give a high distinctive howl. The attenuator may be used to adjust the sound level of individual howlers at their respective station.

The elementary wiring diagrams (figs. 6-12 and 6-13) illustrate the simplicity of the circuit.

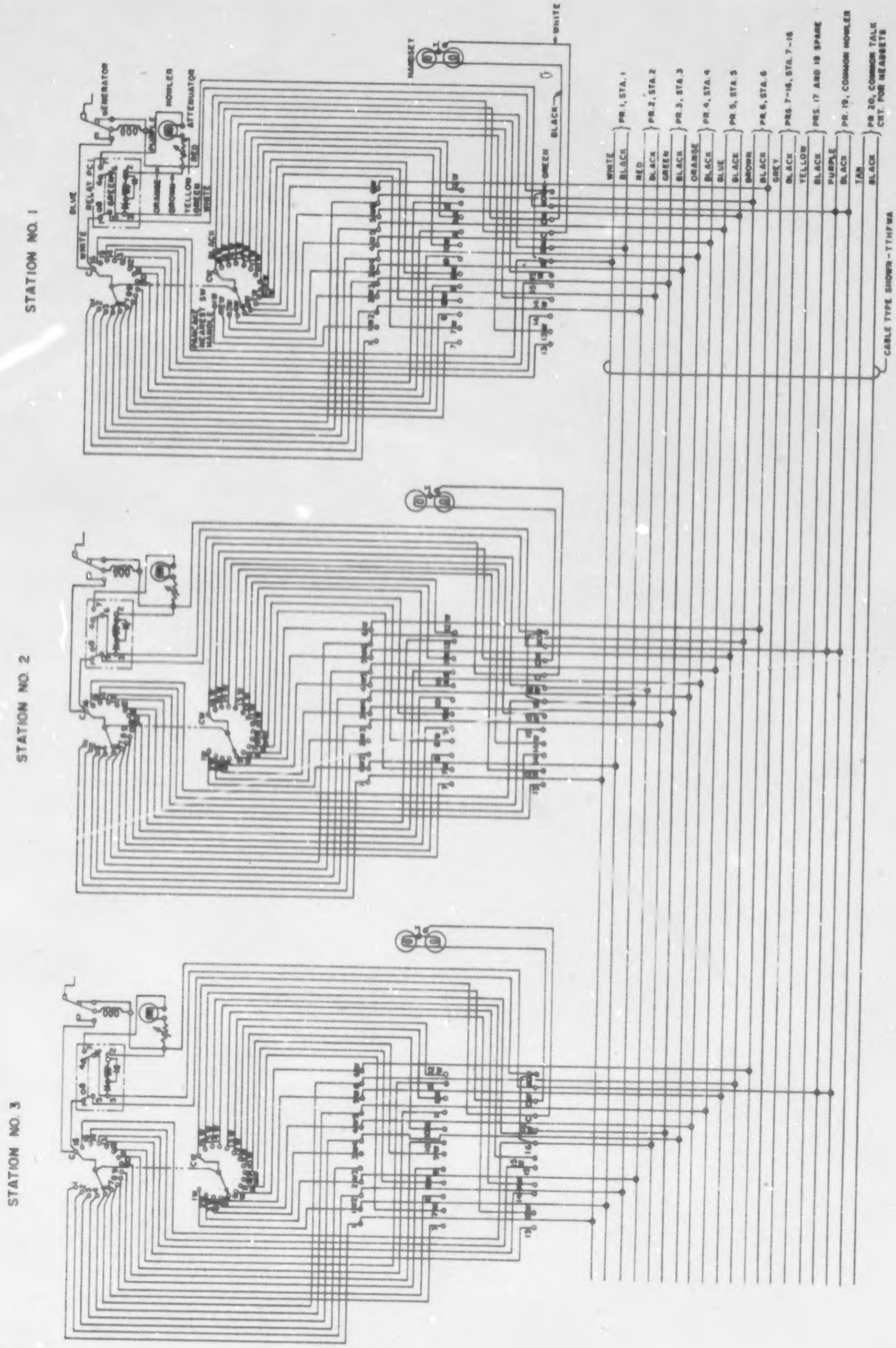
CIRCUIT A

Circuit A is for the convenience of the ship's officers in calling pantry attendants and orderlies. Calls are provided from all cabins; staterooms, except those equipped with ship's service telephones; and wardrooms to the respective pantries and orderlies. Circuit A calls are provided also from all sick-bay berths and isolation wards to the attendant's desk in the sick bay. Circuit A consists of bells and buzzers at the orderly and pantry stations and nonwatertight pushbuttons in the various cabins, staterooms, and messrooms. Where a station is to be signaled by more than one pushbutton, a drop-type annunciator is installed in addition to the bell or buzzer.

Three simplified call-bell circuits are shown in figure 6-14. These simplified circuit connections apply to circuit A as well as to circuit E.

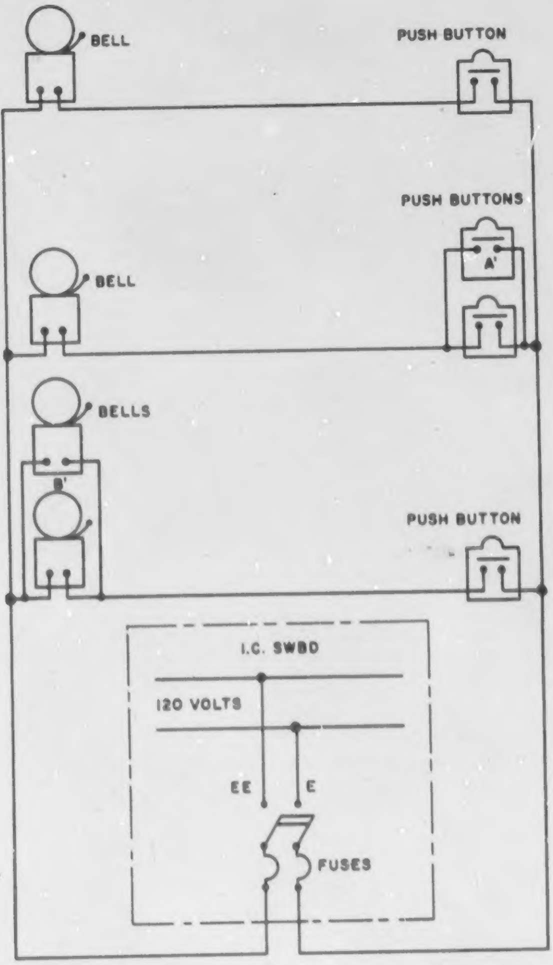
The upper branch circuit, with one bell and one pushbutton in series with each other, is used to call a single station from one location.

The center branch circuit, with two pushbuttons in parallel with each other and in series with the bell, is used to operate one bell from two remote locations.


STATION NO. 1
STATION NO. 2
STATION NO. 3
GENERATOR
HOWLER
ATTENUATOR
HANDSET
WHITE
BLACK
GREEN
BLUE
RELAY
PURPLE
RED
ORANGE
BROWN
YELLOW
CS
WHITE
BLACK
RED
BLACK
GREEN
BLACK
ORANGE
BLACK
BLUE
BLACK
BROWN
BLACK
GREY
BLACK
YELLOW
BLACK
PURPLE
BLACK
TAN
BLACK
PR. 1, STA. 1
PR. 2, STA. 2
PR. 3, STA. 3
PR. 4, STA. 4
PR. 5, STA. 5
PR. 6, STA. 6
PRS. 7-16, STA. 7-16
PRS. 17 AND 18 SPARE
PR. 19, COMMON HOWLER
PR. 20, COMMON TALK CKT. FOR HEADSETS
CABLE TYPE SHOWN-TTHFWA

140.74

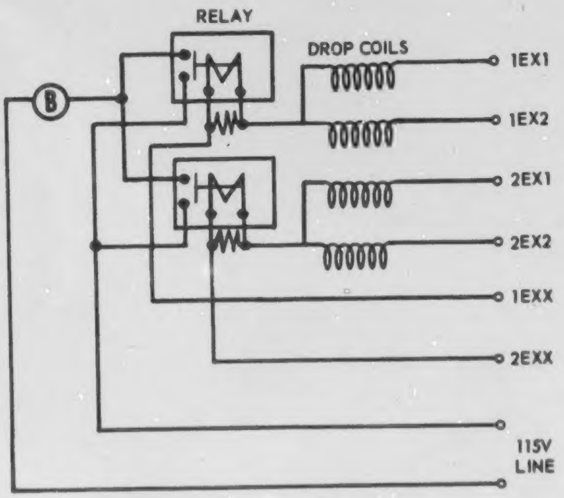
Figure 6-13.–Modification of call signal station, type IC/D for multiple talking and selective ringing.



27.292
Figure 6-14.—Simple call-bell system.

The lower branch circuit, with two bells in parallel with each other and in series with one pushbutton, is used to operate two bells from one location.

Note that the bells or signaling devices (fig. 6-14) are connected to the side of the line bearing the negative designation, EE. This arrangement is used on a-c circuits that have no polarity but in which one side of the line arbitrarily is designated as EE for convenience.



27.293
Figure 6-15.—Two-circuit, four-drop annunciator.

ANNUNCIATORS

Call-bell stations that have several sound-powered handsets, each on a different circuit, are provided with annunciators to identify the circuit of the station that originates the call.

Annunciators used with E-call circuits are of the drop type. The drop, or target, is embossed with the circuit letter and is held mechanically in the nonindicating position. When the circuit is energized by operating a pushbutton at the calling station, an electromagnet causes the target to drop to the indicating position. The drops are returned to their normal, or nonindicating, positions by a hand-operated reset button.

Annunciators used with A-call circuits are similar to those used with E-call circuits except that in A-call circuits the drop is embossed with the number of the stateroom, or location of the calling station, instead of the circuit letter.

A simple diagram for a 2-circuit, 4-drop annunciator is shown in figure 6-15. When a pushbutton is operated, the proper annunciator drops and the bell rings. The alarm bell rings only while the pushbutton is closed. One side of each drop and one side of an audible-signal relay are connected together so that when the external circuit is closed by the pushbutton, the current flows through the drop and the relay. The relay is energized and closes its contacts to the audible signal. The annunciator may be equipped with one or more relays as required by the number of associated circuits, but utilizing a common audible signal.

SOUND-POWERED TELEPHONE AMPLIFIER AM-2210/WTC

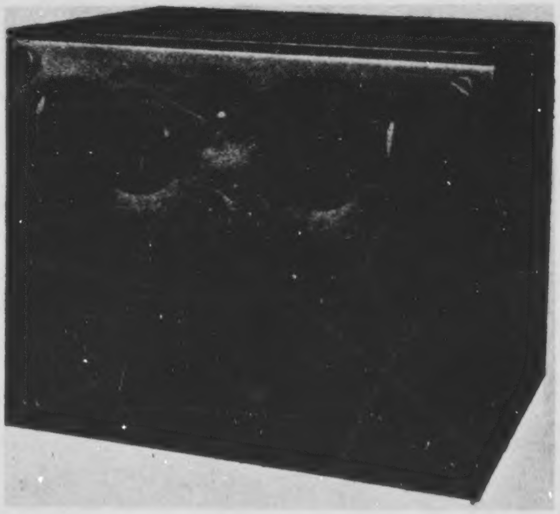
In high noise level areas such as engineering control, steering engine rooms, and gun mounts, it is often difficult if not impossible to hear telephone conversations, even over the best maintained circuits. Recognizing this, the Navy developed the sound-powered telephone amplifier to assist communications in these vital areas. The transistorized AM-2210/WTC, one of the more recent designs presently in wide use throughout the fleet, meets the following requirements with a high degree of reliability:

1. Amplify one-way communications in a two-way sound-powered system using existing sound-powered headsets. (That is, amplify the voice to the gun mounts but not the voice from it.)
2. Supply six outlet headsets and two loudspeakers.
3. Be fail-safe on power loss or component failure. (Allow normal level.conversation.)
4. Operate on 115-volt 60-hertz a-c power.

When operating under normal conditions, the AM-2210/WTC (fig. 6-16) receives signals from the remote telephone line, amplifies them, and transmits the amplified signal to as many as six headsets and two loudspeakers. Direct talk-back between any of the six headsets and the remote line is carried out at normal sound-powered level, the amplifier being disconnected upon the actuation of any of the six talk switches.

When the amplifier is deenergized or certain predetermined casualties occur, direct two-way communications between local and remote stations are not interrupted. They are however, conducted at a normal sound-powered level.

Electrically the unit consists of an audio amplifier, a switching circuit, and a power supply, with all possible circuitry being static in nature. The incorporation of transistors in the audio and switching circuits as well as silicon junction diodes in the power supply, creates a high reliability static condition. Figure 6-17 gives a functional display of the varied components. One relay (K1) is employed in the switching circuit.



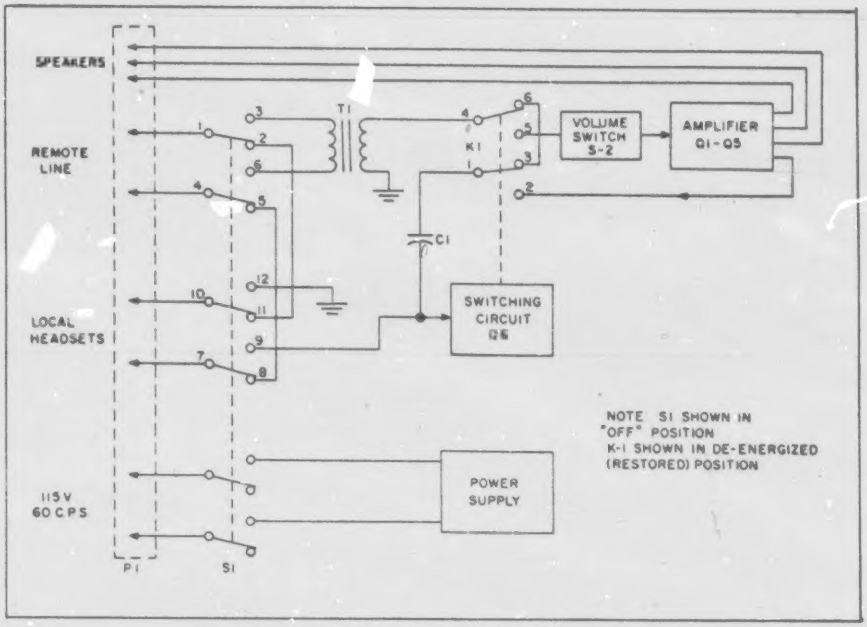
140.71
Figure 6-16.—Audio frequency amplifier AM2210/WTC.

AUDIO AMPLIFIER

The amplifier consists of a low level, three-transistor amplifier, (Q1 thru Q3), and a power amplifier (Q4 and Q5), with negative feedback employed throughout. The output transformer T3 (not shown) has two secondaries; the first is used with the loudspeakers and the latter, a tapped winding is used for as many as six sound-powered telephone outlets.

SWITCHING CIRCUIT

The switching circuit is activated when the amplifier is energized. With power available and neither local nor remote talk switches closed, the relay K1 is operated. When operated, the depression of a remote talk switch will have no effect upon K1, that is, it will remain operated. When power is available and one of the six local talk switches is depressed, however, the circuit to K1 is changed and K1 restores (as discussed later in this chapter).



NOTE S1 SHOWN IN "OFF" POSITION
K-1 SHOWN IN DE-ENERGIZED (RESTORED) POSITION

140.72

Figure 6-17.—Functional diagram of AM2210/WTC.

Figure 6-18 is a functional representation of the K1 switching circuit showing K1 in an energized and operated condition. The receiver element of the local headset is in series with a d-c blocking capacitor, thereby presenting a high resistance when the talk switch is open. Closing the talk switch connects the headset across the line, giving the headset a d-c resistance of approximately 4.8 ohms. It is the function of the switching circuit to sense this change from high impedence to low resistance that takes place with the depression of one of the six headset talk switches.

Resistor R31 provides a bias to the base of Q6, which normally holds Q6 in a saturated state, maintaining K1 in an operated condition. When the local talk switch is closed, the base of Q6 is connected to ground through the 4.8 ohms of the mouthpiece. Presently the voltage across Q6 from base to ground becomes less than the emitter bias voltage provided by the divider R32 and R33; therefore the transistor becomes reverse biased and Q6 becomes nonconductive, deenergizing and restoring K1.

The incoming and outgoing voice signals are coupled through capacitor C1 of the amplifier while the intent of CR1 is to protect Q6 from surges while it is in the cutoff state.

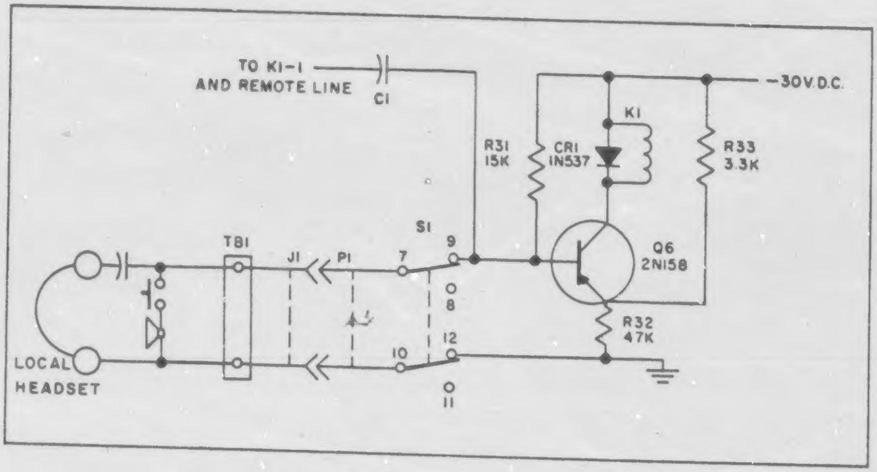
As can be seen from the foregoing, the restoration of K1 will result on normal communications at sound powered level between all stations; the amplifier being effectively bypassed. The advantage of this circuitry is that any casualty, such as a loss of power, will allow normal sound-powered communications.

POWER SUPPLY

The power supply is basically a full-wave rectifier receiving its power through switch S1 (fig. 6-17) and the fuses on the face of the unit. A neon glow lamp and a volume control potentiometer are also located on the unit's face.

MAINTENANCE

Although by no means trouble free, the AM-2210/WTC is a highly reliable unit. When trouble does occur it often is caused by improper operating procedures by personnel, or a failure


TO K1-1
AND REMOTE LINE
C1
-30V.D.C.
K1
R31
15K
CR1
1N537
R33
3.3K
S1
9
7
8
12
10
11
TB1
J1
P1
Q6
2N158
R32
47K
LOCAL
HEADSET

140.73

Figure 6-18.—Switching circuit of AM2210/WTC.

in external circuitry. Often personnel who operate the unit are not aware of the operational capabilities of the unit and a brief indoctrination will clear an apparent trouble. One procedure which has caused some failures in the unit is the practice of taping close the talk button of one of the local headsets. This violation of circuit integrity will result in K1 being continually restored and bypassing the amplifier system.

In earlier models of the amplifier, transistors Q4 and Q5 were found subject to grounding. Authorized modifications will correct the difficulty.

CHAPTER 7

ALARM AND WARNING SYSTEMS

Although they often constitute little more than a power source, a switch, and an alarm device, the alarm and warning systems of the various Interior Communications systems are extremely vital to any ship's operation. One would not operate his automobile with the low oil pressure or high engine temperature alarm glaring. So it is with the machinery and other components of any ship's alarm and warning system. It just doesn't make sense to operate a turbine when the bearings are overheating or the oil pressure is low.

Alarm and warning systems installed in Navy ships provide audible and/or visual signals when abnormal or dangerous conditions occur. The principal components of alarm and warning systems are switches or contact makers, relays, thermostats, and audible and visual signals. The systems, and their circuit designations and classifications are listed in table 7-1.

SWITCHES AND RELAYS

Switches used with alarm and warning systems include manual switches, pressure and thermostatic switches, mechanical switches, and water switches as discussed in chapter 3 of this training manual. Relays are used to open and close circuits that may operate indicating lights, annunciator drops and/or audible signals.

AUDIBLE SIGNALS

There are many types of audible signals in use aboard Navy ships. The type of signal used depends upon the noise level of the location, and the kind of sound desired. The principle types of audible signals are bells, buzzers, horns, and sirens. Electronic signals are being used for some applications on new construction ships.

Bells and Buzzers

Bells used with alarm and warning systems may be either a-c or d-c operated, watertight or watertight explosion-proof construction, with circular or cowbell shape gongs.

Alternating-current bells have 4 types of gongs: Circular 3-inch diameter, type IC/B8S4; Circular 4-inch diameter, types IC/B5DSF4 and IC/B5S5; Circular 8-inch diameter, types IC/B2S4 (watertight), and IC/B2S4 (watertight explosion-proof); and cowbell type IC/B3S4 (fig. 7-1).

Direct-current bells have 3 types of gongs: Circular 2 1/2-inch diameter, type IC/B1D4; Circular 8-inch diameter, type IC/B2D4 (fig. 7-2); and cowbell type IC/B3D4.

Buzzers are used only in relatively quiet spaces. Buzzer, type IC/Z1D4 (fig. 7-3), is d-c operated and has make and break contacts. Buzzer, type IC/Z1S4, is a-c operated and has no contacts.

Horns and Sirens

Nonresonated horns (types IC/H1D4, IC/H4D2, and IC/H4D3) utilize a diaphragm actuated by a vibrating armature to produce sound of the required intensity.

Resonated horns (fig. 7-4A), types IC/H2S4 and IC/H2D4, also use diaphragms, and in addition, have resonating projections to give the sound a distinctive frequency characteristic. The resonated horn is designed in a variety of types, differing as to intensity, frequency, or power supply.

Motor-operated horns (fig. 7-4B), types IC/H8D3, IC/H8D4, and IC/H8S3, utilize electric motors to actuate the sound producing diaphragms.

Sirens are used in very noisy spaces or to sound urgent alarms. The sound is produced by an electric motor driving a multiblade rotor past a series of ports or holes in the housing (fig. 7-5). The air being forced through the ports gives a siren sound, the frequency of which depends upon the number of ports, the number of rotor blades, and the motor speed.

Table 7-1.—Alarm and Warning Systems

Circuit	System	Importance	Readiness Class
BZ	Brig cell door alarm and lock operating	NV	4
BW	Catapult Bridle Arresterman safety Ind.	NV	1
CX	Bacteriological Lab. & Pharmacy Comb. Refer Failure	NV	1
DL	Secure communications space door position alarm	NV	1
DW	Wrong direction alarm	V	2
EA	Reactor compartment or fireroom emergency alarm	NV	1
IEC	Lubricating oil low pressure alarm-propulsion machinery	SV	2
2EC	Lubricating oil low pressure alarm-auxiliary machinery	SV	1
1ED	Generator high temperature alarm	SV	1
2ED	Oxygen-nitrogen generator plant low temperature alarm	NV	1
EF	Generator bearing high temperature alarm	SV	1
EG	Propeller pitch control, hydraulic oil system low pressure alarm	SV	2
EH	Gas turbine exhaust high temperature alarm	SV	1 (aux. machinery) 2 (prop. machinery)
EJ	Feed pressure alarm	SV	1
1EK	Pneumatic control air pressure alarm	NV	2
3EK	Catapult steam cutoff and alarm	NV	2
EL	Radar cooling lines temperature and flow alarm	NV	1
EP	Gas turbine lubricating oil high temperature alarm	SV	1 (aux. machinery) 2 (prop. machinery)
1EQ	Desuperheater high temperature alarm	SV	1
2EQ	Catapult steam trough high temperature alarm	SV	2

27.352.1

Table 7-1.—Alarm and Warning Systems—Continued

Circuit	System	Importance	Readiness Class
3ES	Reactor fill alarm	V	1
ET	Boiler temperature alarm	NV	1
EV	Toxic vapor detector alarm	SV	1
1EW	Propulsion engines circulating water high temperature	SV	1
2EW	Auxiliary machinery circulating water high temperature	SV	1
EZ	Condenser vacuum alarm	SV	2
F	High temperature alarm	SV	1
4F	Combustion gas and smoke detector	SV	1
9F	High temperature alarm system-ASROC launcher	SV	1
11F	FBM storage area temperature and humidity alarm	SV	1
12F	Gyro ovens temperature and power failure alarm	SV	1
FD	Flooding alarm	NV	1
FH	Sprinkling alarm	SV	1
FR	Carbon dioxide release alarm	NV	1
FS	Flight Deck Readylight Signal system	NV	2
FZ	Security alarm (CLASSIFIED)	V	1
4FZ	Torpedeo alarm (CLASSIFIED)	V	1
HF	Air flow indicator and alarm	SV	1
LB	Steering Emergency Signal system	NV	2
LS	Submersible steering gear alarm	SV	2
MG	Gas turbine overspeed alarm	SV	1 (aux. machinery) 2 (prop. machinery)
NE	Nuclear facilities air particle detector alarm	NV	1

27.352.2

Table 7-1.—Alarm and Warning Systems—Continued

Circuit	System	Importance	Readiness Class
NH	Navigation Horn Operating System	NV	2
QA	Air lock warning	NV	1
QD	Air filter and flame arrester pressure differential alarm, or gasoline compartment exhaust blower alarm	V	1
QX	Oxygen-nitrogen plant ventilation exhaust alarm	SV	1
RA	Turret emergency alarm	NV	1
RD	Safety observer warning	NV	2
RW	Rocket and torpedo warning	SV	3
4SN	Scavenging air blower high temperature alarm	V	2
SP	Shaft position alarm	NV	2
TD	Liquid level alarm	NV	1
1TD	Boiler water level alarm	NV	1
2TD	Deaerating feed tank water level alarm	NV	1
5TD	Reactor compartment bilge tank alarm	SV	1
6TD	Primary shield tank, expansion tank level alarm	NV	1
7TD	Reactor plant fresh water cooling expansion tank level alarm	NV	1
8TD	Reactor secondary shield tank level alarm	NV	1
9TD	Lubricating oil sump tank liquid level alarm	SV	1
11TD	Induction air sump alarm	SV	1
12TD	Diesel oil sea water compensating system tank liquid level alarm	SV	1
14TD	Auxiliary fresh water tank low level alarm	NV	1
16TD	Pure water storage tank low level alarm	SV	1
17TD	Reserve feed tank alarm	NV	1
18TD	Effluent tanks and contaminated laundry tank high level alarm	V	1

27.352.3

Table 7-1.—Alarm and Warning Systems—Continued

Circuit	System	Importance	Readiness Class
19TD	Sea water expansion tank low level alarm	SV	1
20TD	Gasoline drain tank high level alarm	SV	1
21TD	Moisture separater drain cooler high level alarm	NV	1
24TD	Reactor plant on board discharge tank level alarm	V	1
25TD	Crossover drains high level alarm	SV	1
29TD	Sonar dome fill tank low level alarm	SV	1
30TD	JP-5 fuel drain tank high level alarm	SV	2
TW	Train Warning system	NV	1
W	Whistle Operating System	NV	2

Legend:

V—Vital SV—Semivital NV—Nonvital.
1—Continuously energized-supply switch color code yellow.
2—Energized when preparing to get underway, while underway, and until the ship is secured-supply switch color code black.
3—Energized during condition watches -supply switch color code red.
4—Energized only when required-supply switch color code white.
All electronic type alarm systems formerly designated as circuits CA, FC, FW, G, GD, GJ, GN, and FP are now classified as a portion of the respective announcing system with which they are associated.

27.352.4

Electronic Signal Units

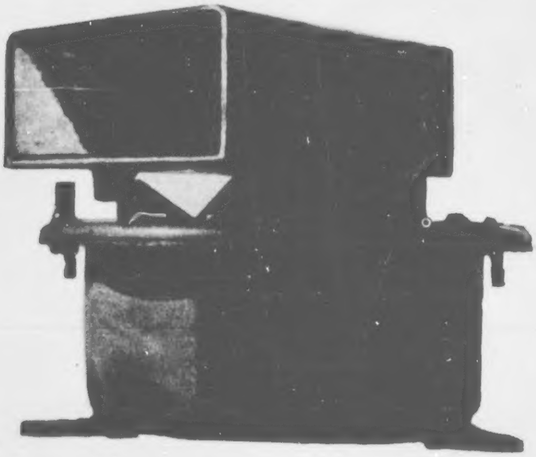
The type IC/E1D1 electronic signal unit (fig. 7-6) is designed as a bus failure alarm. The unit contains an electronic solid state oscillator which drives a 2-inch howler unit to provide an audible signal upon loss of power on the supervised bus. The unit also provides a visual signal upon loss of power.

The power for the oscillator is provided by a small nickel-cadmium battery which is maintained on a low charge when the supervised bus is energized. The unit will operate on 115 volts, d-c or a-c (60 Hz or 400 Hz) without modification.

The IC/E3D2 electronic signal unit (fig. 7-7) is designed for use with Navy standard alarm system. The unit contains a solid state oscillator which generates three distinct tones; a steady siren; a siren wail; and a siren yelp tone.

VISUAL SIGNALS

Visual signals are used in a great many alarm and warning systems to provide an additional means of identifying the alarm being sounded. Audible and visual signals are often used together. In noisy spaces audible signals are supplemented by visual signals, and in brightly lighted spaces visual signals are supplemented by audible signals. In many instruments the same audible device is used in combination with several visual indicators. The

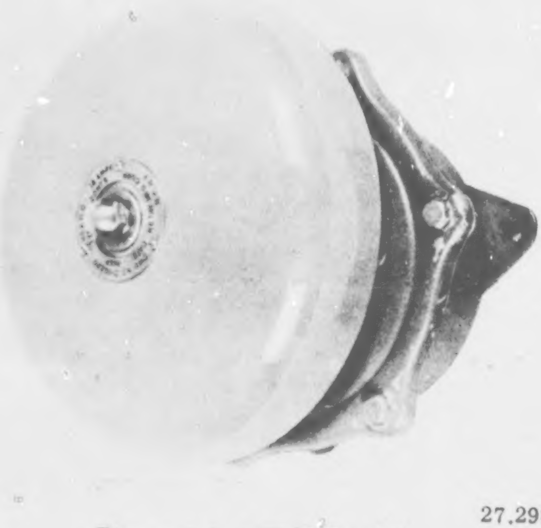


27.297
Figure 7-1.—IC/B3S4 bell.

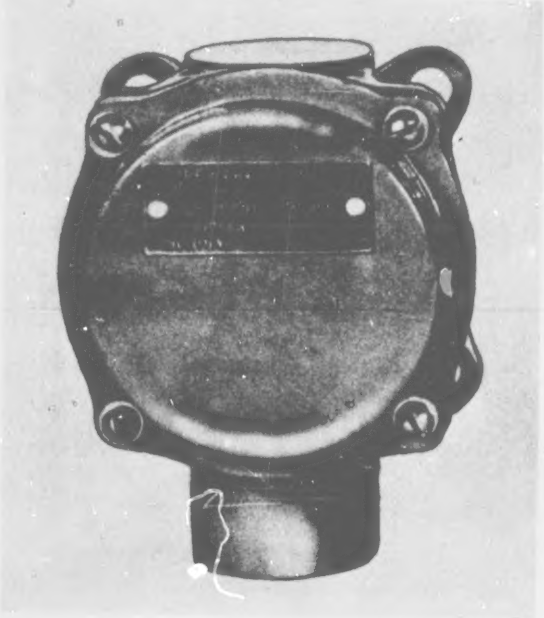
principal types of visual signals are lamp type indicators and target drum type alarm indicators.

Lamp Type Indicators

Standard watertight, lamp type indicators are designed as single-dial, 2-dial, 3-dial, 4-dial, and 6-dial units (fig. 7-8A). Two 115-volt lamps are connected in parallel and mounted behind each dial. The use of two lamps in parallel provides protection against the loss of illumination in case one lamp burns out. A colored-glass disk and sheet-brass burns out. A colored-glass disk and sheet-brass target engraved with the alarm identification are illuminated from the rear by the two lamps. Glass disks are furnished in eight standard colors, depending upon the application.



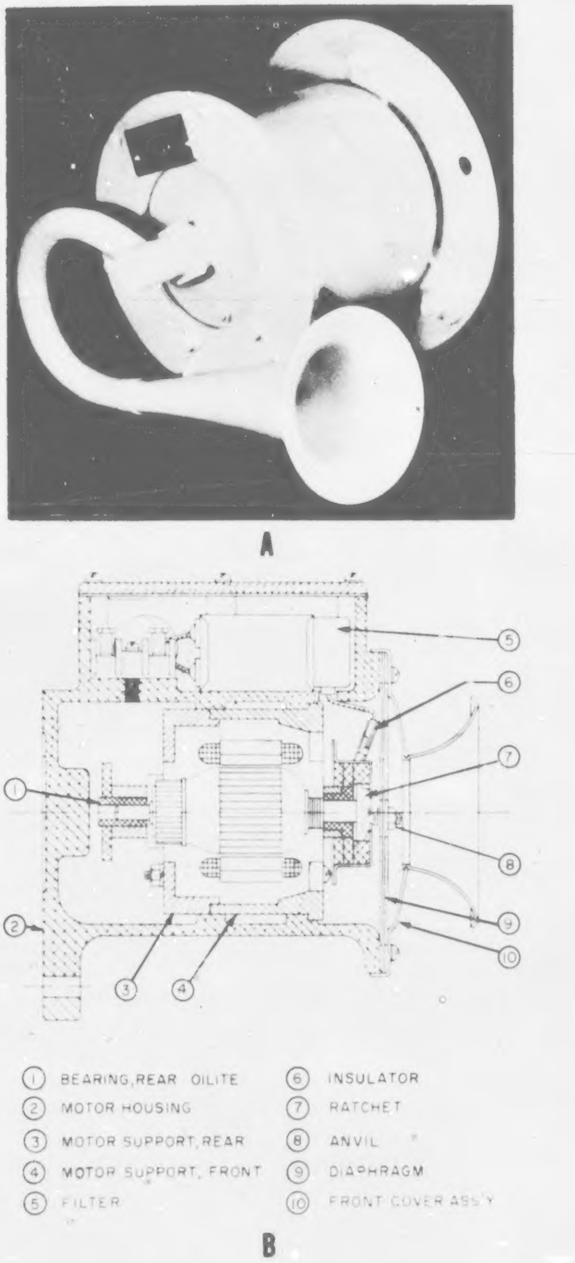
27.298
Figure 7-2.—IC/B2D4 bell.



27.299
Figure 7-3.—IC/Z1D4 buzzer.

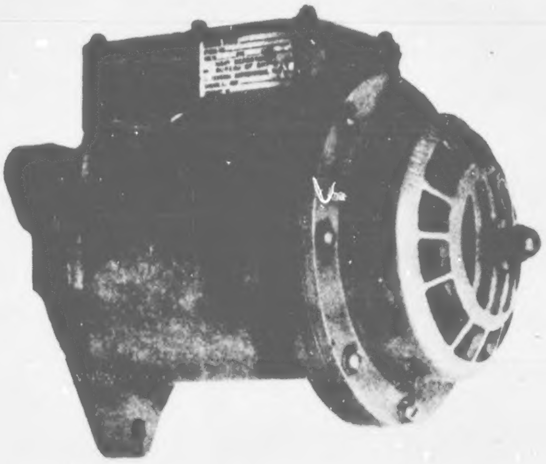
The 115-volt lamps are in parallel with the audible signal. When the audible signal sounds, the lamps illuminate the colored glass and brass target of the indicator and identify the alarm being sounded. This type of indicator is used with various alarm systems

Standard watertight lamp type indicators are designed also as 2-dial variable-brilliancy, (fig. 7-8B), 2-dial fixed-brilliancy, and 4-dial variable-brilliancy unit. Two 6-volt lamps are connected in parallel and mounted behind each dial. A colored jewel disk and sheet-brass target are illuminated from the rear by the two lamps.


A
5
6
7
1
8
9
2
10
3
4
1 BEARING, REAR OILITE
2 MOTOR HOUSING
3 MOTOR SUPPORT, REAR
4 MOTOR SUPPORT, FRONT
5 FILTER
6 INSULATOR
7 RATCHET
8 ANVIL
9 DIAPHRAGM
10 FRONT COVER ASS'Y
B

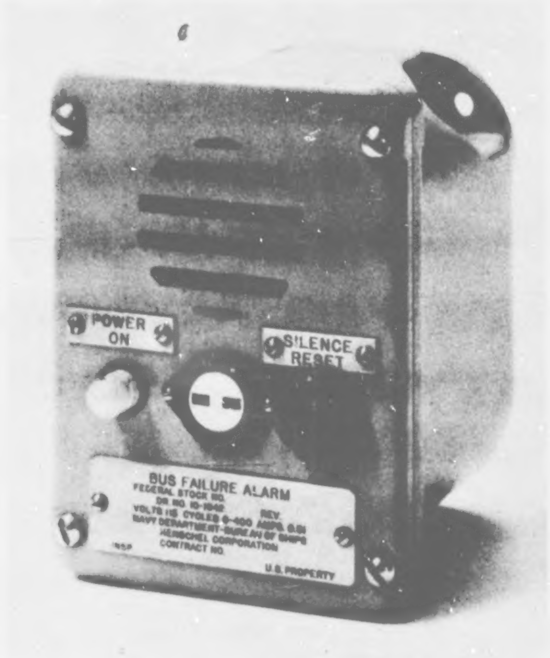
27.300

Figure 7-4.—Motor operated and resonated horns.



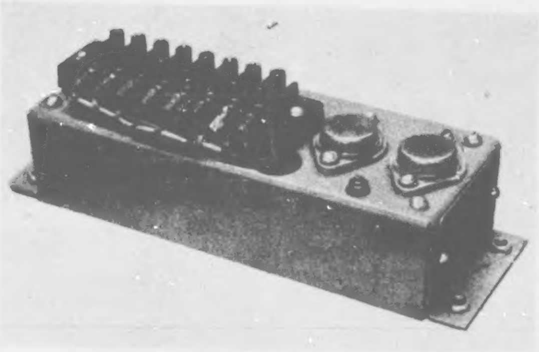
27.301

Figure 7-5.—Siren.


POWER ON
SILENCE RESET
BUS FAILURE ALARM
FEDERAL STOCK NO.
VOLTS 115 CYCLES
NAVY DEPARTMENT-BUREAU OF SHIPS
HERSCHEL CORPORATION
CONTRACT NO.
U.S. PROPERTY

27.302

Figure 7-6.—Electronic signal unit type IC/E1D1.



140.120

Figure 7-7.—Type IC/E3D2 electronic signal unit.

Special lamp type indicator panels are designed to give good visibility at all viewing angles. These panels contain rows of prism-shaped red and green jewels. Each indicator has two 6-volt lamps in parallel. This type of indicator is used in the main ballast tank and hull opening indicator system.

Another special lamp-type indicator consists of two indicator lights (red and green). Six 115-volt lamps in parallel are provided for each indication. This type of indicator is used in the traffic control ready light system on aircraft carriers.

Alarm Indicators

Each two-line alarm unit provides complete equipment for supervising two circuits. Each circuit requires an alarm-target relay, a supervisory-target relay, and a three-position, toggle type test switch. The two-line unit (fig. 7-9), has two alarm relays mounted side by side at the rear and near the bottom of the unit panel. Each relay has an indicator drum that projects into square openings in the face of the panel. The two test and cutout switches are mounted above the alarm relays. The two supervisory relays, with their indicator drums, are mounted above the test and cutout switches.

The relays (fig. 7-10) are of similar construction. However, the number of turns on the coils and the contact arrangement are different. Note that when the armature (1) of the alarm relay operates, it rotates the target drum (2B) through an eccentric, and closes the contacts for the audible alarms by moving roller (3). However, the supervisory target relay is designed to be normally operated; its alarm contact is closed when the relay is deenergized.

The alarm drum has a red section that rolls into view when the alarm target relay is operated. The supervisory drum shows a yellow section when it is deenergized.

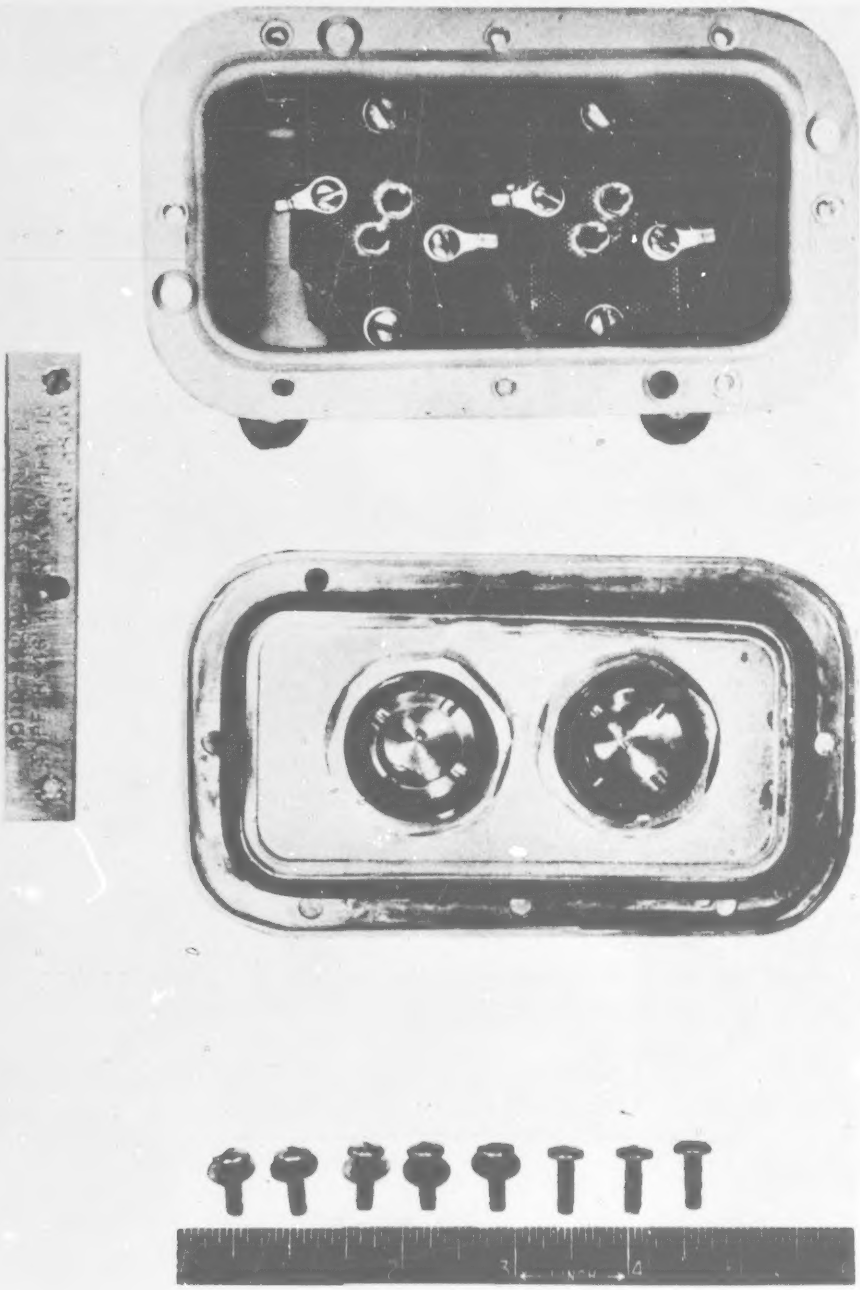
The two relays are in series with the alarm device, which is a mercury thermostat in the high-temperature alarm (fig. 7-11).

As the operation of a relay is dependent on the ampere-turns, the current can be limited so that there will be the required ampere-turns to operate one coil and insufficient ampere-turns to operate a second coil with fewer turns. The supervisory resistor (fig. 7-11) is in series with both relays under normal conditions and acts as a current-limiting device.

Under normal conditions the current that flows in the supervisory circuit (fig. 7-11), is supplied by a transformer and rectifier. The current flows from the negative side of the rectifier through the operated supervisory target relay, the supervisory resistor, the lower section of the mercury thermostat or alarm device, the energized but not operated alarm target relay, and back to the rectifier. The total resistance of the circuit supplied by the rectifier is 9675 ohms. When the temperature rises at the alarm device, and the mercury reaches the upper contact, the 7000-ohm supervisory resistor is shunted out of the circuit. This reduces to 2675 ohms the total resistance of the circuit supplied by the rectifier. This increase in current is enough to operate the alarm target relay. The alarm-target relay in operating rotates its red target into position and closes the contact that completes the circuit to the extension relay, which is supplied power from the primary side of the transformer. When the extension relay operates, it closes the contacts to complete the circuit to the bell. The bell furnishes the audible alarm and the target drum the visual signal, to indicate which circuit has the high-temperature alarm.

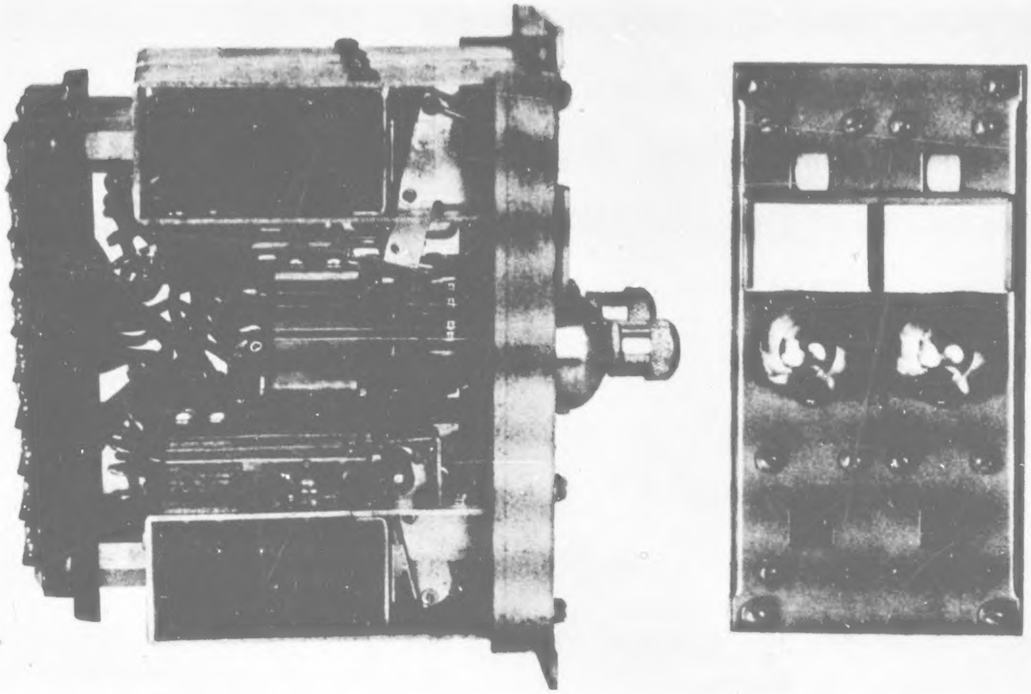
A loss of current in the supervisory circuit will cause the supervisory-target relay to release its armature. When the amature drops down it closes the alarm contact to complete the circuit from the primary side of the transformer to the buzzer. The target drum furnishes the visual signal of the circuit in trouble.

An open circuit in either side of the transformer, the rectifier, or the supervisory circuit will cause the buzzer to sound.



27.303.1

Figure 7-8.—Lamp type indicator.



27.304

Figure 7-9. — Two-line alarm unit.

Each electromagnet actuates contacts for energizing common audible signals. A nameplate is provided on the panel to identify the alarm being sounded. A switch is provided to test the circuit and to cut off the alarm.

FIRE ALARM SYSTEMS

There are three indications of fire; heat or temperature rise, smoke or combustible gases, and flame. The Navy uses two methods of detection in its circuit F fire alarms. The temperature-rise method, which uses a mercury thermostat, is found on the older naval ships. On new construction, conversions, and ammunition ships, in addition to the temperature rise system, there is a combustion gas and smoke detector system (circuit 4F).

HIGH-TEMPERATURE ALARM SYSTEM

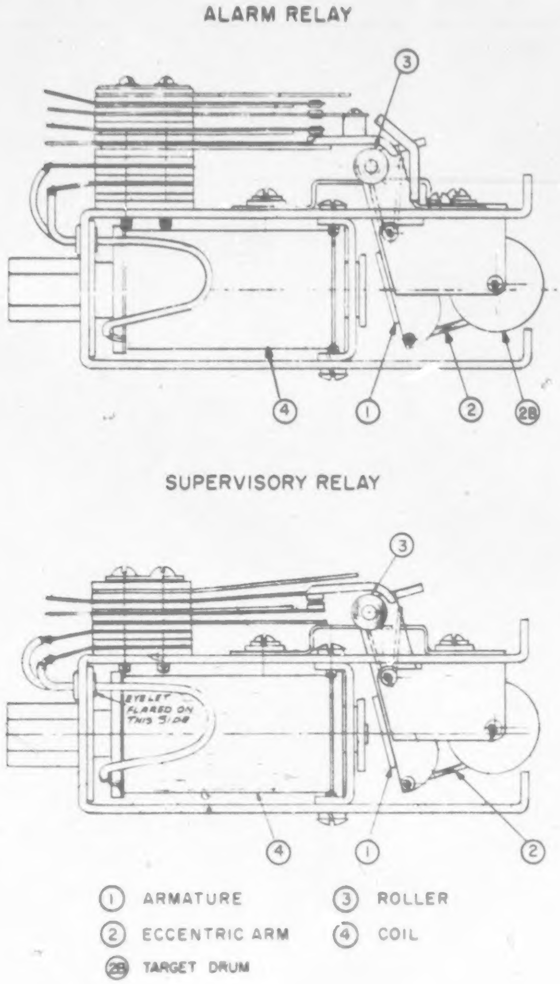
The high-temperature alarm system (circuit F) is an electrical system installed aboard ship to detect and warn of fires or overheated conditions in important compartments and spaces.

All alarm systems used in Navy Ships are of the closed-circuit supervisory type. Each circuit of the system consists primarily of one trouble-alarm relay, one cutout key, one alarm signal, and one thermostat or group of thermostats.

Alarm Panels and Switchboard

The alarm switchboard is installed in a station, which is continuously manned while both underway and in port. The alarm switchboard operates on 120-volt, a-c 60-hertz or 120-volt, d-c service supplied from the main IC switchboard. The alarm switchboard consists of an upper section and a lower section.

The UPPER section comprises the alarm panel (fig. 7-12). This panel contains an alarm bell, a test light, a trouble buzzer, two ground-detector lamps, a pilot lamp, a trouble test


ALARM RELAY
③
④
①
②
㉘
SUPERVISORY RELAY
③
EYELET FLARED ON THIS SIDE
④
①
②
① ARMATURE
③ ROLLER
② ECCENTRIC ARM
④ COIL
㉘ TARGET DRUM

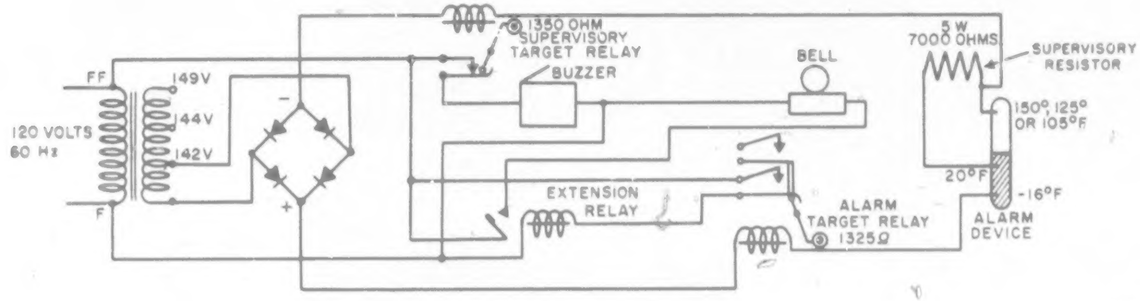
27.305
Figure 7-10.—Alarm and supervisory relays.

lamp, an alarm test lamp, and a test key. An extension signal relay, capable of operating up to four fire alarm bells located at other stations on the ship, is mounted at the rear of the alarm panel. As long as the power supply to the switchboard is maintained, the pilot light at the center of the panel glows.

The LOWER section consists of as many 10-line or 20-line panels as are necessary to accommodate the total number of high-temperature, circuit F, or water-sprinkling circuit FH stations aboard the ship. Six 10-line panels capable of accommodating 60 lines are shown in figure 7-11. The switchboard apparatus for each two lines is mounted together in a removable alarm unit. Five or ten of these 2-line units are arranged to make up a 10-line or a 20-line panel. Each line supervises one thermostat or one group of thermostats. Each circuit is provided with a separate test key with a drum trouble-indicator target above, and a drum fire-indicator target below. A nameplate located above the test key identifies the compartment or the spaces served by that line.

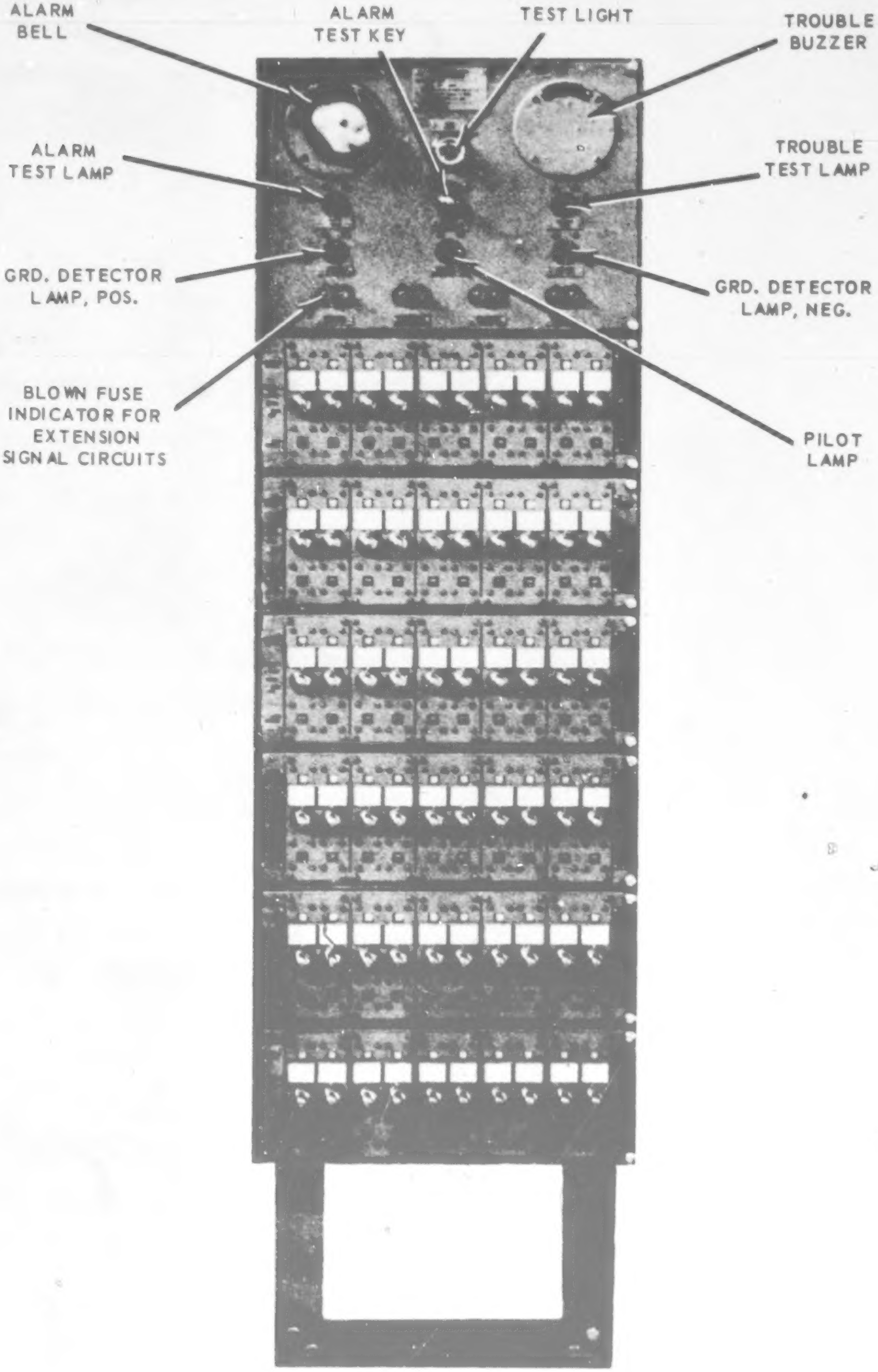
TYPE IC/SM ALARM SWITCHBOARD.—The type IC/SM Supervisory Alarm switchboard provides for centralized monitoring of remotely located sensors by means of compact modular plug-in units. The switchboard (fig. 7-13) houses the audible speaker, speaker control switch, lamp dimmer, up to 50 individual display modules, the power supply, fuses, and ground detector.

The alarm module (fig. 7-14) has a manual selector switch for placing the module in either NORMAL, STANDBY, CUTOUT or TEST modes and a divided, lighted display, either half of which can show a steady or flashing red light or no light as required.


③ 1350 OHM SUPERVISORY TARGET RELAY
BUZZER
BELL
5 W
7000 OHMS
SUPERVISORY RESISTOR
FF
149V
144V
142V
120 VOLTS
60 Hz
F
-
+
150°, 125° OR 105°F
20°F
-16°F
ALARM DEVICE
EXTENSION RELAY
ALARM TARGET RELAY
③ 1325Ω

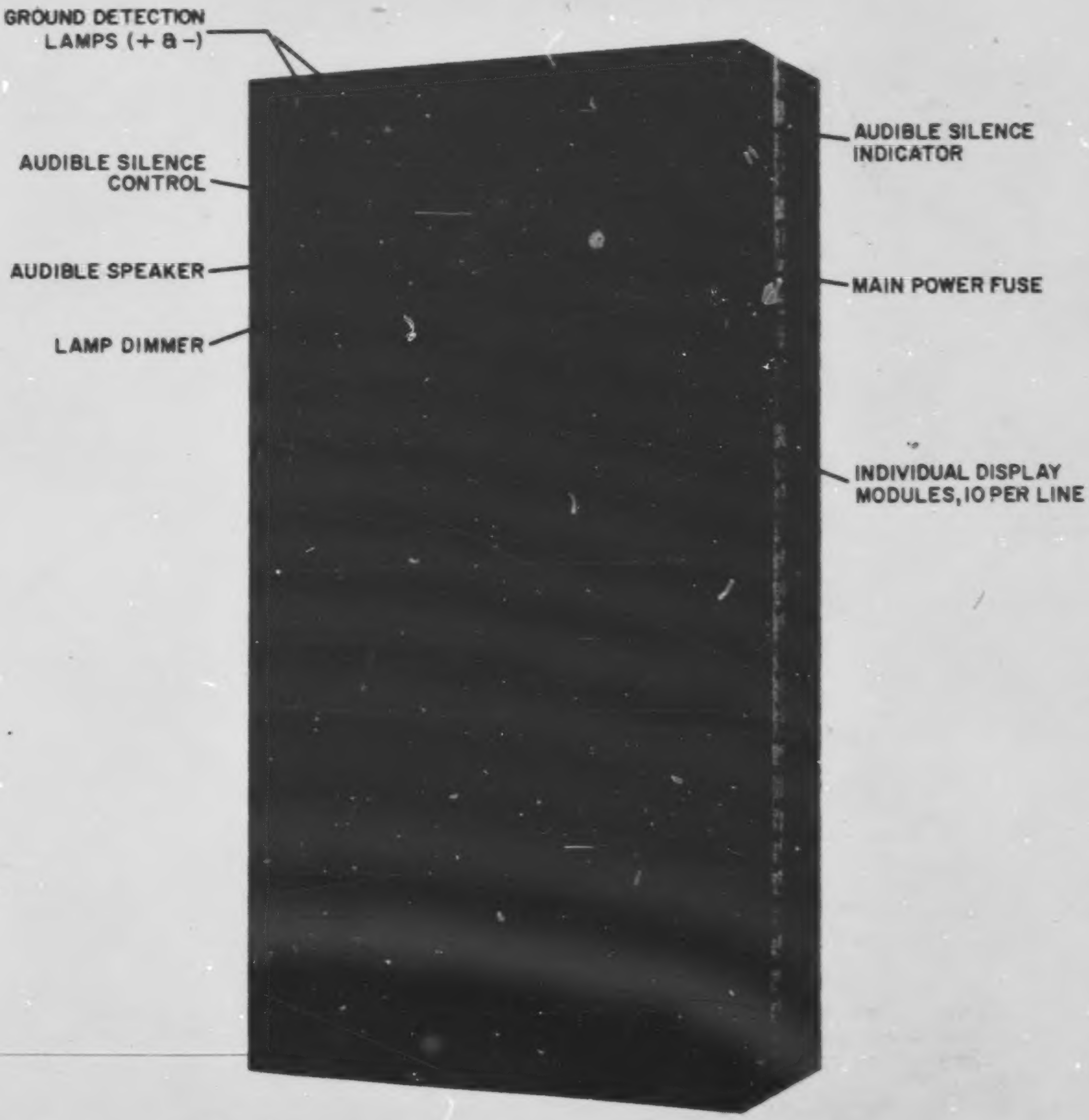
27.306

Figure 7-11.—High-temperature alarm circuit.


ALARM BELL
ALARM TEST KEY
TEST LIGHT
TROUBLE BUZZER
ALARM TEST LAMP
TROUBLE TEST LAMP
GRD. DETECTOR LAMP, POS.
GRD. DETECTOR LAMP, NEG.
BLOWN FUSE INDICATOR FOR EXTENSION SIGNAL CIRCUITS
PILOT LAMP

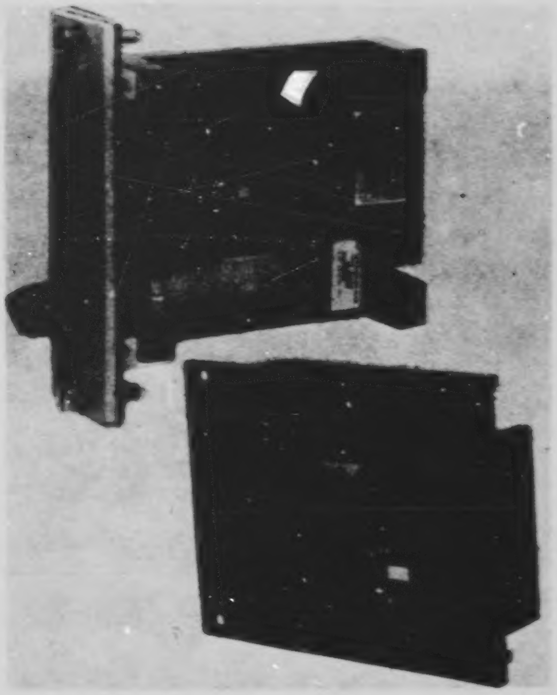
27.307

Figure 7-12. —Alarm switchboard.


GROUND DETECTION LAMPS (+ & -)
AUDIBLE SILENCE CONTROL
AUDIBLE SPEAKER
LAMP DIMMER
AUDIBLE SILENCE INDICATOR
MAIN POWER FUSE
INDIVIDUAL DISPLAY MODULES, 10 PER LINE

140.121

Figure 7-13.—IC/SM switchboard showing—50 line with 10 active modules in place.



140.122

Figure 7-14.—IC/M alarm module.

In the NORMAL mode, the upper lamp is "on steady" and the lower lamp is off (fig. 7-15). During an alarm condition, the upper lamp flashes and a wailing tone alarm sounds.

To acknowledge an alarm the switch is shifted to STANDBY and the audible alarm is silenced while both the upper and lower lamps are "on steady." After the alarm condition is cleared, the lower lamp flashes while the upper lamp goes out; a pulsating tone alarm is produced to inform the operator to return the switch to NORMAL.

If the sensor circuit should open, the upper lamp goes out while the lower lamp is "on steady;" a pulsating tone alarm sounds when the module is in the NORMAL mode. Then to work on the circuit safely, you deenergize the sensor circuit by placing the mode selector switch to CUTOUT. In this position the lamps indicate as they do for supervisory failure: top lamp out, lower lamp "on steady," no audible alarm.

Placing the mode selector switch in the TEST position simulates an alarm condition. For this position the upper lamp flashes while the lower lamp is out; a wailing tone alarm sounds just as it does for an alarm condition in the NORMAL mode.

The lamp dimmer affects all the module indicating lights except for the alarm condition lights which continue to flash at full brilliance.

Thermostats

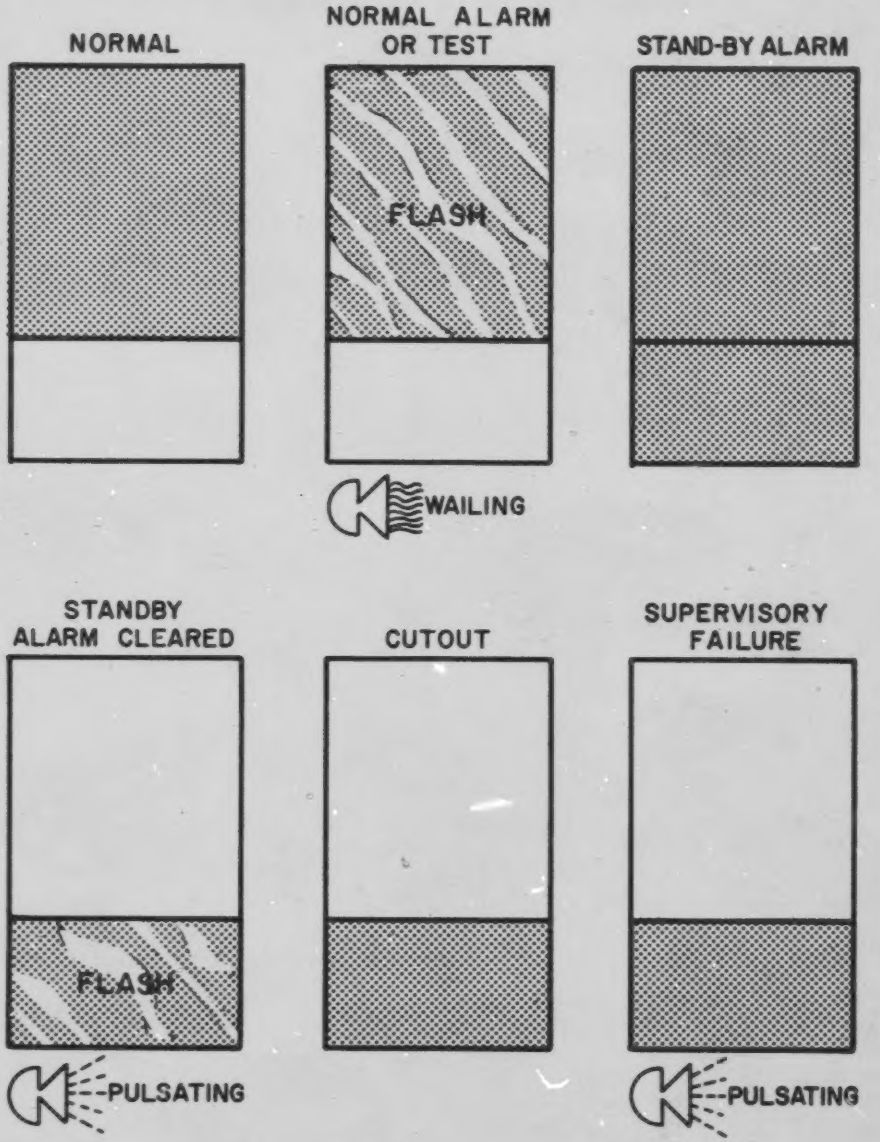
As previously mentioned, the detection of fires or overheated conditions is accomplished by means of mercury thermostats (fig. 7-16). These thermostats are installed at selected locations throughout the ship. Thermostats are installed on the overhead and require a free circulation of air for efficient operation. Barriers that would obstruct the free circulation of air should never be placed around thermostats in any compartment. On the other hand, thermostats should not be installed in the path of supply ventilation.

The thermostats are designed to close their contacts at temperatures of 105°, 125°, or 150° F. Except for differences in temperature ratings, the thermostats are similar. A defective thermostats are similar. A defective thermostat must be replaced with one having the same temperature rating.

Temperature Ratings

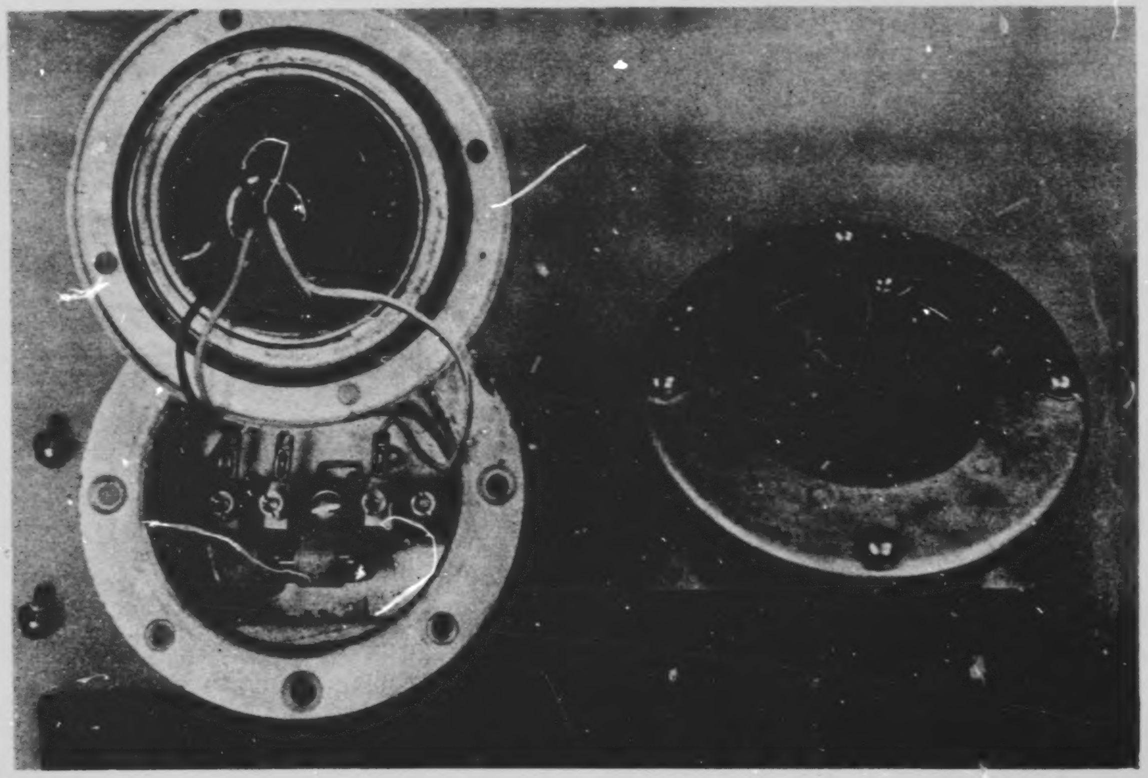
The 125° and 150° F thermostats are normally installed in storerooms, paint lockers, and similar spaces used to house combustible stores. The 105° F thermostat is normally installed in magazines. Because its function is to detect rises in temperature above the limits that are safe for magazine spaces, the upper contact is located so that the resistor is shorted out when the temperature reaches 105° F.

As many thermostats as are needed for the prompt detection of a fire can be connected to any one line. If more than one thermostat is used in a compartment, only one supervisory resistor is required, as shown in figure 7-17A and B. With such a connection, when any one of the thermostats in the group is overheated, the alarm operates. These thermostats or groups of thermostats are connected to the alarm switchboard by multiconductor cable. Each circuit on the alarm switchboard is marked to designate one compartment, and the thermostat or group of thermostats, installed in each


NORMAL
NORMAL ALARM OR TEST
FLASH
STAND-BY ALARM
WAILING
STANDBY ALARM CLEARED
FLASH
PULSATING
CUTOUT
SUPERVISORY FAILURE
PULSATING

140.123

Figure 7-15.—IC/SM visual displays and audible outputs.



27.308

Figure 7-16. —Mercury thermostat type IC/J125.

compartment is connected to the circuit marked for that compartment.

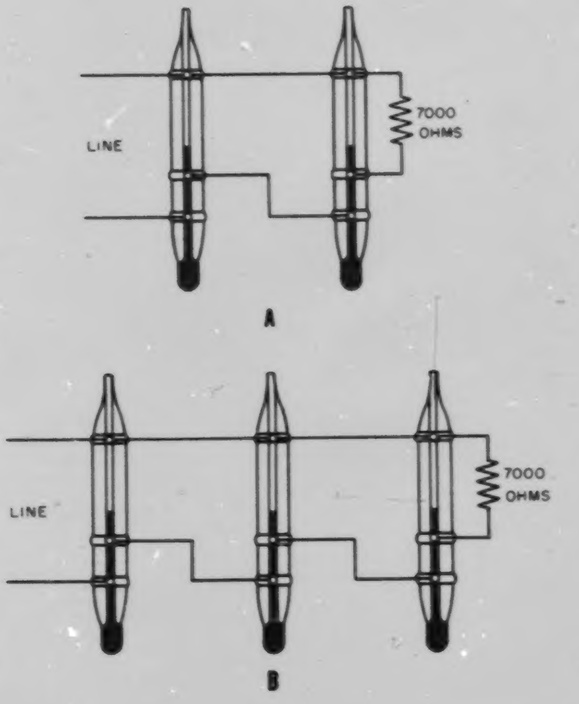
Operation

When conditions are normal, direct current (approximately 0.0p2 amp) flows from the full-wave rectifier (fig. 7-11), through the supervisory target relay, the supervisory resistor, to the intermediate contact of the thermostat, through its mercury column to the lower contact, and through the alarm target relay to the rectifier. The current is limited by the 7000-ohm resistor to a value required to operate the supervisory target relay. This value is smaller than that required by the alarm-target relay.

In case of fire or other high-temperature condition the mercury expands and rises in the thermostat, the supervisory resistor is shorted out, and the current rises to a maximum value in the circuit. The increase in current is large enough to cause the alarm target relay to operate. The relays target is revolved and the alarm contacts close, to sound the alarm.

When an open circuit occurs, such as in the secondary of the transformer or a broken thermostat bulb, the supervisory current no longer flows in the circuit and the supervisory relay deenergizes. This action closes its contacts and completes the circuit to the buzzer and the target is rolled to show yellow.

A switch is provided in each circuit for use in testing the circuit and for silencing either the fire bells or trouble buzzer when they sound an alarm. Complete tests and operating instructions are included on the MRC for the system and in the manufacturer's technical manual provided for the alarm equipment installed in your ship.



27.309
Figure 7-17.—Thermostat connections.

COMBUSTION GAS AND SMOKE DETECTOR SYSTEM

The combustion gas and smoke detector system, circuit 4F, detects and warns of the presence of combustion gases or smoke. The alarm circuits are similar to, and operate in the same manner as the high-temperature fire alarm circuits. A combustion gas and smoke detector head is used as the alarm device.

OPERATING PRINCIPLES

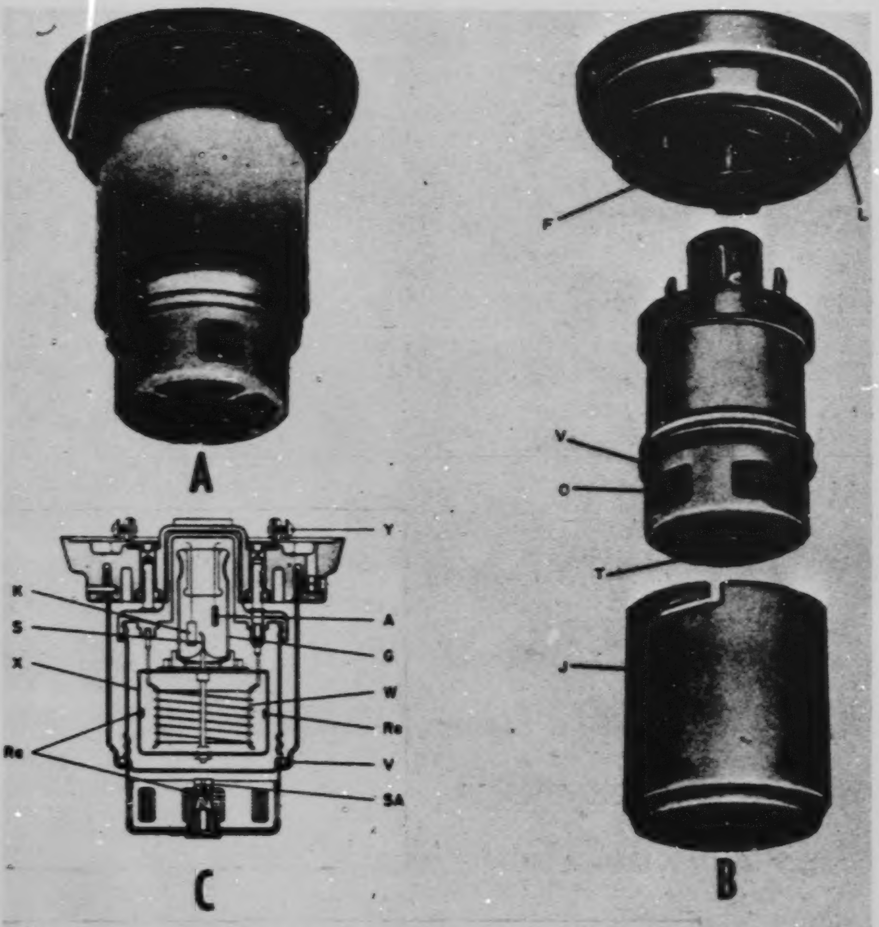
The combustion gas and smoke detector head (fig. 7-18A), is installed on the overhead in the compartment or space to be protected. A four-pin polarized plug fits into a socket base allowing easy replacement (fig. 7-18B). The major units of the detector head are the inner and outer chambers and the cold cathode tube (fig. 7-18C). The detector compares the air in the inner chamber with the air in the outer chamber. When combustion gases and/or smoke are present in the air of the outer chamber, the cold cathode tube fires and supplies the current to operate the alarm relay.

The air in the inner and outer chamber is made conductive by a small quantity of radium (fig. 7-18C). Alpha particles given off by the radium have the ability to ionize air into positive ions and negative electrons. If this ionized air is introduced into an electric field, a current will flow. This principle is shown in figure 7-19. A potential from battery, B, is applied to the plates, P1 and P2. The air between the plates is ionized by the radium. The charged particles move in the direction indicated by the arrows. A sensitive galvanometer measures the current, the value of which depends on the strength of the radium source, and within limits, the voltage of the battery. With low potentials, part of the ions and electrons collide and neutralize each other. It is only when the potential reaches a certain limit that all of the ions formed reach the plates. This is known as the saturation point. Beyond this point, the current remains virtually constant regardless of the increase of potential. Only a change in the gas in the chamber will cause a change in the current flow when the unit is operating at the saturation point.

The presence of combustion gas or smoke particles between the plates (fig. 7-19), would cause a sharp decrease in current flow through the galvanometer. This is true because the combustion gas and smoke particles are many times larger and heavier than the air molecules, and require a stronger radioactive source to become ionized. Also, the ionized combustion gas and smoke particles move much slower in the electric field, and are practically all neutralized by free electrons before reaching one of the plates.

BASIC CIRCUIT

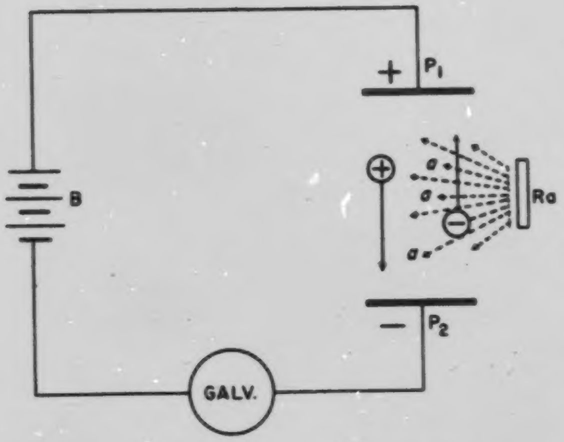
In the basic circuit of the detector system (fig. 7-20), the normal voltage across chamber X is 130 volts d-c, and 90 volts d-c across chamber O and tube elements S and K. The breakdown voltage between the plate, A, and cathode, K, of the cold cathode tube is greater than 270 volts. Therefore with 220 volts applied to A and K, the tube will not fire until triggered by the starter, S. The tube is triggered when the voltage between S and K reaches 110 volts.



X-INNER OR REFERENCE CHAMBER; O-OUTER OR DETECTING CHAMBER; Ra-RADIUM SOURCES; SA-SENSITIVITY ADJUSTMENT CAP; T-SENSITIVITY ADJUSTMENT SCREW; G-GAS DISCHARGE (COLD CATHODE) TUBE; A-ANODE; K-CATHODE; S-STARTER ELECTRODE; W-INNER WIRE GRID ELECTRODE; J-LOCKING SHELL; V-O RING; F-SOCKET BASE; L-LOCKING SET SCREW; Y-TERMINAL SCREWS.

27.310

Figure 7-18.—Combustion gas and smoke detector head.



Ra - RADIUM
α - ALPHA RADIATION
⊕ - IONS
⊖ - ELECTRONS
B - BATTERY
GALV. - GALVANOMETER
P_1 AND P_2 - PLATES OR ELECTRODES

27.311

Figure 7-19.—Ionization principle.

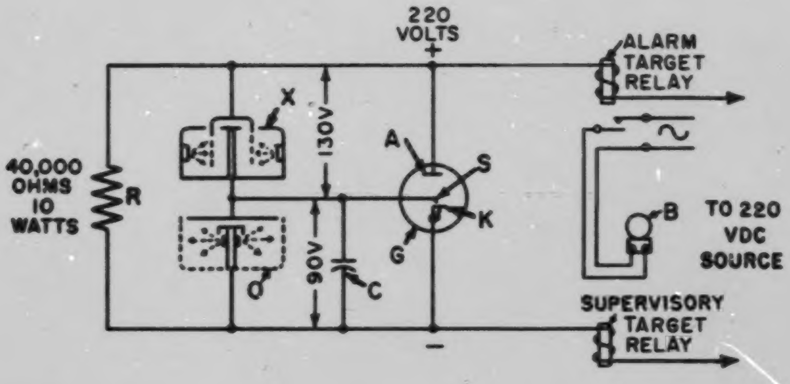
With no smoke or combustion gas present in the outer chamber, only enough current flows to energize the supervisory target relay. The current flow is from the d-c source (a full-wave silicon diode rectifier) through the outer and inner chambers, the supervisory resistor R, and back to the d-c source. When smoke or a combustion gas enters chamber O, it increases the resistance of that chamber which causes the current to decrease through both chambers. As the resistance of chamber X is fixed, the voltage across it decreases. This causes the voltage across chamber O and across S and K to increase to 110 volts triggering the cold cathode tube. The tube conducts from K to A furnishing the required current to operate the alarm target relay.

SPRINKLING ALARM SYSTEM

The sprinkling alarm system, circuit FH, is basically the same as the high-temperature alarm system except that water or pressure switches are used instead of mercury thermostats.

LUBRICATING-OIL, LOW-PRESSURE ALARM SYSTEM

The purpose of the lubricating-oil, low-pressure alarm system, circuits 1EC and 2EC,



X - INNER OR REFERENCE CHAMBER; O - OUTER OR DETECTING CHAMBER,
G - GAS DISCHARGE (COLD CATHODE) TUBE; A - ANODE; K - CATHODE;
S - STARTER ELECTRODE; C - TRIGGER CAPACITOR;
B - ALARM BELL; R - SUPERVISORY RESISTOR.

27.312

Figure 7-20.—Basic circuit of detector system.

is to sound an alarm whenever the pressure in the lubricating-oil supply line to the main engine and reduction gear, or to the turbine-driven or diesel-driven generators, and other auxiliary machinery falls below a predetermined minimum limit. Where the system is used for the main engines the circuit is designated, 1EC, and when used for either turbine-driven or diesel-driven generators and other auxiliaries the circuit is designated, 2EC. Both circuits are energized from individual switches on the local IC switchboard.

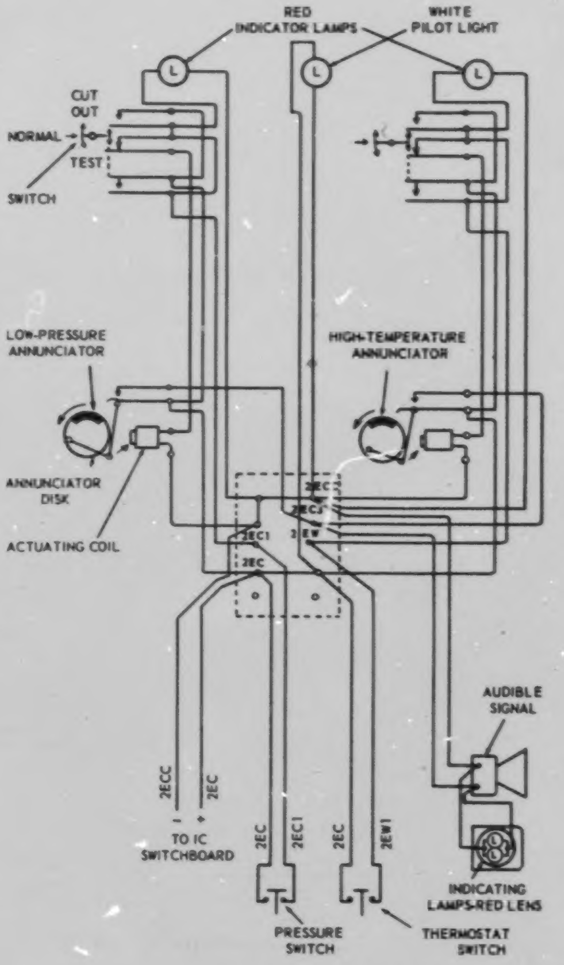
An EC circuit includes one or more pressure type switches installed in the lubricating-oil lines of the associated equipment. A dial-light indicator, drum type annunciator, and siren are energized when the switch is closed because of a decrease in oil pressure. The control panel of the lubricating-oil, low-pressure alarm is located near the operating control board of the machinery on which the switch is installed.

CIRCULATING-WATER, HIGH-TEMPERATURE ALARM SYSTEM

The circulating-water, high-temperature alarm system, circuits 1EW and 2EW, automatically indicates when the circulating-water temperature of the main propulsion diesel engines or the large auxiliary diesel engines rises above the predetermined maximum limit. When the system is used for the main engines the circuit is designated, 1EW, and when used for auxiliary engines the circuit is designated, 2EW. The circulating-water, high-temperature alarm system is usually combined with the lubricating-oil, low-pressure alarm system (fig. 7-21), and consists of temperature-operated switches located in the circulating water lines of the engines. A rise in temperature above a predetermined point closes a thermostatic switch, which energizes a lamp-type indicator, drum-type annunciator, and siren, causing the alarm to sound.

GENERATOR AND GENERATOR BEARING HIGH-TEMPERATURE ALARM SYSTEMS

The generator high-temperature alarm system, circuit 1ED, provides a means of indicating high temperature of the cooling air exhaust of generator sets rated at 500 kw and above. The system consists of thermostatic switches located in the generator exhaust to the cooler, which energize visual and audible signals when the temperature of the circulating air rises above a predetermined limit.

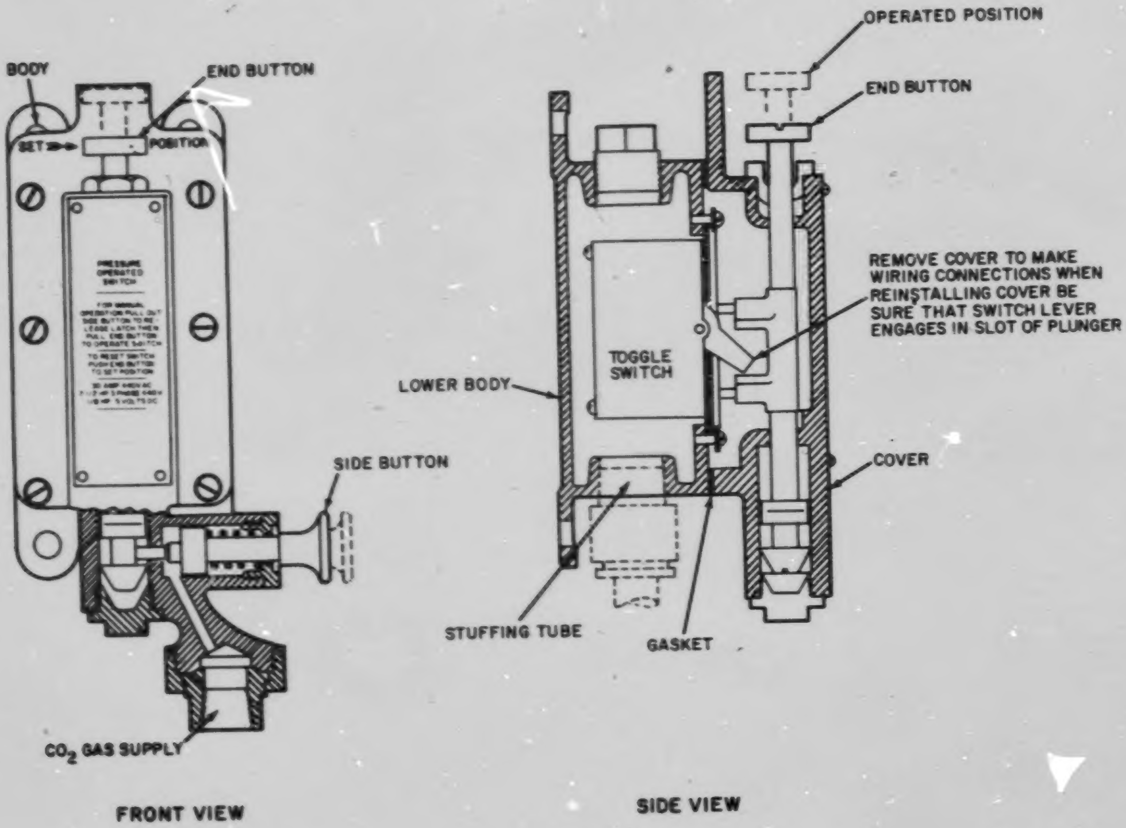


27.313

Figure 7-21.—Schematic of 2EC and 2EW circuits.

The generator bearing high-temperature alarm system, circuit EF, provides a means of indicating high temperatures in the bearings of generator sets of 200 kw and above. Thermostatic switches energize visual and audible signals when a bearing temperature rises above a predetermined limit.

The visual and audible signals for circuits 1ED, and EF are incorporated in the alarm panel of circuit 2EC.


BODY
END BUTTON
SET
POSITION
SIDE BUTTON
CO_2 GAS SUPPLY
FRONT VIEW
OPERATED POSITION
END BUTTON
REMOVE COVER TO MAKE WIRING CONNECTIONS WHEN REINSTALLING COVER BE SURE THAT SWITCH LEVER ENGAGES IN SLOT OF PLUNGER
TOGGLE SWITCH
LOWER BODY
COVER
STUFFING TUBE
GASKET
SIDE VIEW

140.124

Figure 7-22.—Pressure-operated switch for CO_2 release alarm system.

CARBON DIOXIDE (CO_2) RELEASE ALARM SYSTEM

The CO_2 release alarm, cricuit FR, is an alarm system that indicates when CO_2 is being released into a monitored space. It is used primarily in paint lockers and flammable storage and paint storage compartments. The system consists of a pressure-operated switch and an alarm bell. The switch is installed in the CO_2 supply pipe line of the protected space; the alarm bell in the space serviced by the CO_2. The purpose of the alarm is to warn the personnel in the protected space that the CO_2 system has been actuated so they may evacuate the space immediately.

Operation of the system is simple and straight forward. When the CO_2 is released, the pressure of the CO_2 forces the plunger into the operated position. See figure 7-22. The plunger then carries the switch lever to the ON position, causing the bell to operate.

The system may be tested for proper operation by (1) pulling "out" the side button and (2) pulling the plunger "up" to the operated position by the end button. When these steps are taken the alarm bell should ring. To reset the system for normal operation, reverse the procedure: push down on the end button and release the spring-loaded side button.

BOILER TEMPERATURE ALARM SYSTEM

The boiler temperature alarm system, circuit ET, provides a means of indicating boiler steam high temperature in ships having separately fired superheat control boilers. A thermostatic switch located in the main steam line from each boiler energizes a 2-dial lamp type indicator and a horn, when the total steam temperature at the superheater outlet rises above a predetermined limit.

SYSTEMS MAINTENANCE

Alarm and warning system are easy to maintain since the MRCs outline the checks to be performed.

Almost any trouble that will affect system operation gives an audible and/or visual indication. Do not use oil anywhere in the alarm units as it may cause flushovers and short circuits.

The electrodes of all water switches should be cleaned after the system has operated. Clean the electrodes with alcohol and rinse them with distilled water.

Remove all combustion gas and smoke detector heads periodically. Clean the heads and conduct a sensitivity check as described in the manufacturer's technical manual.

Check all indicator lamps frequently, and replace any burned-out lamps.

CHAPTER 8

ANNOUNCING AND INTERCOMMUNICATING SYSTEMS

If you should look for the source of a sound, you will find that something had been set in vibratory motion. It may be that someone shouted or that an object was dropped or struck. In each case something had been made to vibrate and cause the sensation of sound. One sound that human beings produce is voice. Although air is the usual medium for carrying voice to your ears, any elastic material in the form of a solid, liquid, or gas can serve as well or better. Like any other sound, voice cannot travel in a vacuum.

In today's Navy, announcing and intercommunications systems amplify and then transmit the voice so it can reach and be heard by the men aboard ship. With these systems, which are the heart of interior communications, the "word" is passed quickly and clearly. This chapter explains the operating principles of installed and portable sound systems and describes the types and characteristics of the microphones and loudspeakers in the systems.

SOUND EQUIPMENT

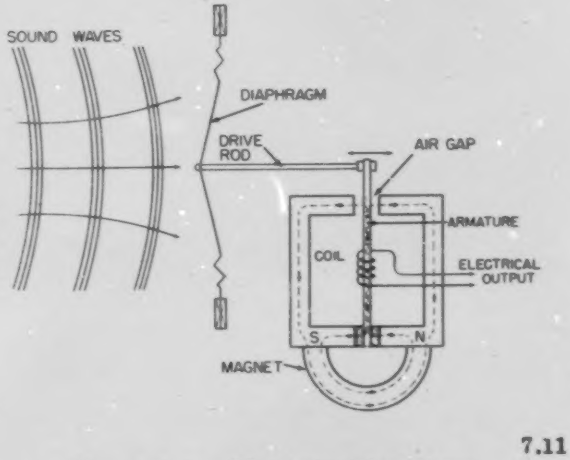
All sound and announcing systems consist basically of an amplifier, a microphone, and a loudspeaker. The microphone converts the sound energy into electrical energy having the same waveform as the sound energy. The ouput from the microphone is applied as a signal voltage to the amplifier. The output power from the amplifier has the same waveform as the sound energy that is applied to the microphone. The loudspeaker reconverts the electrical energy from the amplifier into sound energy at a higher volume level than the original sound. In shipboard installations many loudspeakers are operated from the same amplifier. Each loudspeaker produces sound having the same waveform as the original sound applied to the microphone.

TYPES OF MICROPHONES

A microphone is a device that converts sound energy into electrical energy. All types of microphones have a metal diaphragm that responds to the vibrations of the sound waves, and some means of changing this mechanical vibration into corresponding electrical signals. The most widely used types of microphones are the (1) magnetic, (2) dynamic, (3) crystal, and (4) carbon types.

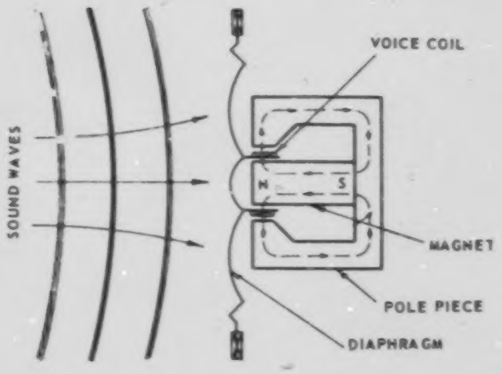
MAGNETIC MICROPHONE.—The magnetic, or moving-armature, microphone (fig. 8-1) consists of a permanent magnet and a coil of wire inside of which is a small armature. Sound waves impinging on the diaphragm cause the diaphragm to vibrate. This vibration is transmitted through the drive rod to the armature which vibrates in a magnetic field, thus changing the magnetic flux through the armature.

When the armature is in its normal position midway between the two poles, the magnetic flux is established across the air gap with no resultant flux in the armature.



7.11

Figure 8-1.—Magnetic microphone.



7.12

Figure 8-2.—Dynamic microphone.

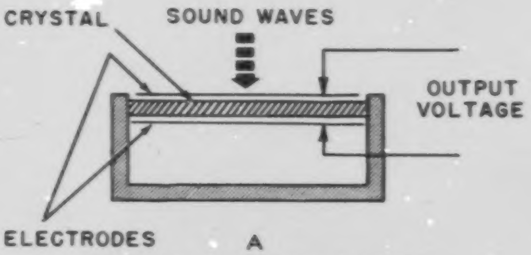
When a compression wave strikes the diaphragm, the armature is deflected to the right. The flux path is directed from the north pole of the magnet across the reduced gap at the upper right, down through the armature, and round to the south pole of the magnet.

When a rarefaction wave strikes the diaphragm, the armature is deflected to the left. The flux path now is directed from the north pole of the magnet, up through the armature through the reduced gap at the upper left, and back to the south pole.

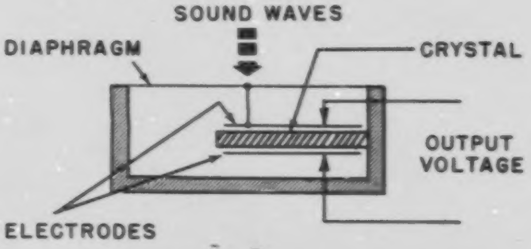
Thus, the vibrations of the diaphragm cause an alternating flux in the armature. The alternating flux cuts the stationary coil wound around the armature and induces an alternating voltage (approximately 10 millivolts at a 150-ohm load) in it. This voltage has the same waveform as the sound waves striking the diaphragm.

The magnetic microphone is the type most widely used in shipboard announcing and intercommunicating systems because it is more resistant to vibration, shock, and rough handling.

DYNAMIC MICROPHONE.—The dynamic, or moving-coil, microphone (figure 8-2) consists of a coil of wire attached to a diaphragm, and a radial magnetic field in which the coil is free to vibrate. Sound waves impinging on the diaphragm cause the diaphragm to vibrate. This vibration moves the voice coil through the magnetic field so that the turns cut the lines of force in the field. This action generates a voltage in the coil that has the same waveform as the sound waves striking the diaphragm.



A
DIRECTLY ACTUATED TYPE



B
DIAPHRAGM TYPE

20.219

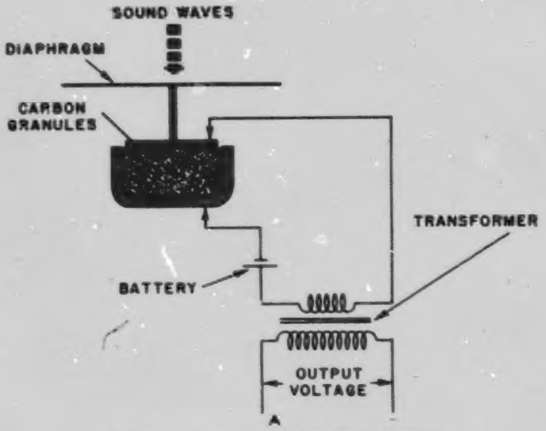
Figure 8-3.—Crystal microphone.

The dynamic microphone requires no external voltage source, has good fidelity, and produces an output voltage of about 0.05 volt when spoken into in a normal tone within a few inches of the diaphragm.

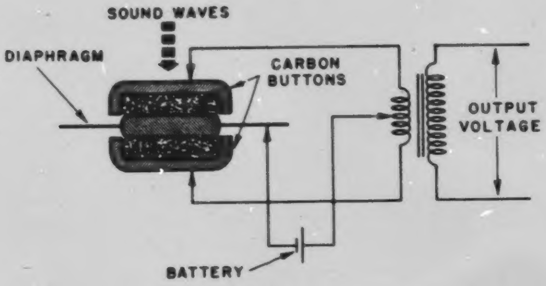
CRYSTAL MICROPHONE.—The crystal microphone utilizes a property of certain crystals—such as quartz, Rochelle salt, sugar, or coal—known as the PIEZOELECTRIC EFFECT. The bending of the crystal resulting from the pressure of the sound wave produces an emf across the faces of the crystal. This emf is amplied to the input of an amplifier.

The crystal microphone (figure 8-3) consists of a diaphragm that is cemented to one surface of the crystal. Metal plates, or electrodes, are attached to the other surface of the crystal. When sound waves strike the diaphragm, the vibration of the diaphragm produces a varying pressure on the surface of the crystal and induces an e.m.f. across the electrodes. This e.m.f. has the same waveform as the sound waves striking the diaphragm.

Rochelle salt is most commonly used in crystal microphones because of its relatively



A
SINGLE-BUTTON CARBON MICROPHONE



B
DOUBLE-BUTTON CARBON MICROPHONE

20.218
Figure 8-4.—Schematic diagram of carbon microphones.

high voltage output. The crystal microphone can produce an output voltage of from 0.01 to 0.03 volt into a load of 1 megohm or more, when subjected to a sound pressure of a normal tone within a few inches of the crystal. However, this crystal microphone is seldom used in naval announcing and intercommunicating systems because of the sensitivity of the crystal element to high temperature, humidity, and rough handling.

CARBON MICROPHONE.—The carbon microphone (figure 8-4) operates on the principle that a changing pressure of a diaphragm applied to a small volume of carbon granules changes its electrical resistance in accordance with the vibrations of the sound waves striking the diaphragm.

The carbon microphone consists of a diaphragm mounted against a mass of carbon granules which are contained in a small cup. In order to produce an output voltage, this microphone is connected in a series circuit containing a battery and the primary of a transformer.

When a direct current flows through the carbon granules, the varying resistance changes the amplitude of the current and produces an alternating voltage in the secondary of the transformer. This voltage has the same waveform as the sound waves striking the diaphragm. The current through this microphone may be as great as 0.1 ampere. The resistance may vary from about 50 to 90 ohms. The voltage developed across the secondary depends upon the ratio of the transformer primary and secondary turns and also upon the change in primary current. Normal output voltage of a typical circuit is from 3 to 10 volts peak at the secondary terminals.

The carbon microphone is not used in shipboard announcing equipment because it requires a polarizing current and has a tendency to amplify certain frequencies more than others.

CHARACTERISTICS OF MICROPHONES

Microphones are rated according to their (1) frequency response, (2) impedance, and (3) sensitivity.

FREQUENCY RESPONSE.—Shipboard announcing and intercommunicating systems are designed to produce maximum speech intelligibility under conditions of high background noise. To achieve this objective the overall frequency response characteristic of the system is altered by cutting off the system response at some lower limit, such as 500 hertz, and by employing an EMPHASIZED frequency response characteristic which rises with increasing frequency at a rate of approximately 6 decibels per octave. The output sound pressure is doubled each time the frequency is doubled for a constant level input to the system. The emphasized speech tends to sound thin and sometimes harsh, but when the masking due to background noise is almost as high as the speech level, the speech appears to cut through the noise.

For good quality, a microphone must convert sound waves into electrical waves that have the same relative magnitude and frequency, without introducing any new frequencies. The frequency range of the microphone must be at least as wide as the desired overall response limits of the system with which it is used.

Except in the case of the emphasized system in which it may be desirable for the microphone to have a rising frequency-response characteristic, the microphone response should be uniform or flat, within its frequency range and free from sharp peaks or dips such as those caused by mechanical resonances.

IMPEDANCE.—Crystal microphones have impedances of several hundred thousand ohms whereas the magnetic and dynamic microphones have impedances that range from 20 to 600 ohms. The impedance of a microphone is usually measured between its terminals at some arbitrary frequency within the useful range such as 1,000 hertz.

The impedance of magnetic and dynamic microphones varies with frequency in much the same manner as that of any coil or inductance—that is, the impedance rises with increasing frequency. The actual impedance of the microphone in shipboard applications is of importance only as it is related to the input load impedance into which the microphone is designed to operate. If the microphone is mismatched with the input impedance, the microphone input is reduced and distortion occurs. All specifications and acceptability tests for naval microphones are based on the designed input load impedance.

SENSITIVITY.—The sensitivity or efficiency of a microphone is usually expressed in terms of the electrical power level that the microphone delivers to a terminating load the impedance of which is equal to the rated impedance of the microphone, compared to the acoustical intensity level or pressure of the sound field that is being picked up.

Most systems rate the microphone in the electrical power level (in decibels below 1 milliwatt) produced by an acoustical pressure of 1 dyne per square centimeter. For example, a crystal microphone rated at 80 decibels means that for an input acoustical pressure of 1 dyne per square centimeter, the electrical output is 80 decibels below one milliwatt, or 10^{-8} milliwatt. Other systems rate the microphone in terms of the voltage delivered to a specified terminating load impedance for an acoustical pressure input of 1 dyne per square centimeter.

It is important to have the sensitivity of the microphone as high as possible. High sensitivity means a high electrical power output level for a given input sound level. High microphone output levels require less gains in the amplifiers used with them and thus provide a greater margin over thermal noise, amplifier hum, and noise pickup in the line between the microphone and amplifier.

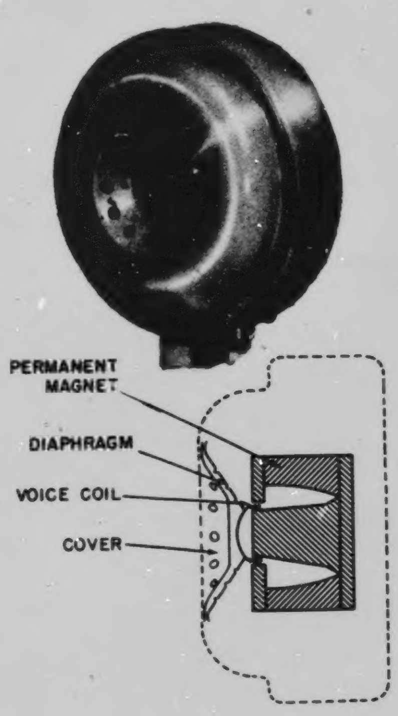
When a microphone must be used in a noisy location, an additional desirable characteristic is the ability of the microphone to favor sounds coming from a nearby source over random sounds coming from a relatively greater distance. Microphones of this type tend to cancel out random sounds and to pick up only those sounds originating a short distance away. When talking into this type of microphone the lips must be held as close as possible to the diaphragm. Directional characteristics that favor sound coming from one direction only, also aid a microphone in discriminating against background noise.

TYPES OF LOUDSPEAKERS

A loudspeaker is a device that converts electrical energy into sound energy and radiates this energy into the air in the form of waves. All loudspeakers consist essentially of a driving mechanism for changing electrical waves into mechanical vibrations that are transmitted to a diaphragm or other vibrating source. This vibrating source is coupled, either directly or by means of a horn, to the air and causes sound to be radiated. The loudspeakers in general use in the Navy are the (1) direct radiator type which radiates sound directly from a vibrating member into the air and (2) horn type which consists of a driving unit combined with a horn to couple the unit to the air.

DRIVING MECHANISMS.—The driving mechanism changes the electrical vibrations into mechanical vibrations. The dynamic, or moving-coil, driving mechanism is the basic type used in Navy loudspeakers. The design of this unit is similar to that of the dynamic microphone, but the pinciple of operation is the reverse of that of the dynamic microphone.

A coil of wire is attached to a diaphragm and rests in a magnetic field. When a varying electric current flows through the coil, a force is exerted on the coil causing it to move back and forth in the magnetic field. The consequent motion of the diaphragm causes the radiation of sound waves which correspond to the variations in the electric current. The electrodynamic and the permanent-magnet types are the two variations in the dynamic loudspeaker. These



7.15

Figure 8-5.—Direct radiator loudspeaker.

types differ only in the method employed for obtaining the magnetic field.

In the ELECTRODYNAMIC LOUDSPEAKER the magnetic field is established by passing a direct current through a field coil that is wound on an iron core. This type requires a source of filtered direct voltage and two additional conductors to carry the field current to the loudspeaker.

In the PERMANENT-MAGNET DYNAMIC LOUDSPEAKER the magnetic field is established by a permanent magnet. All loudspeakers used by the Navy are of the permanent-magnet dynamic type.

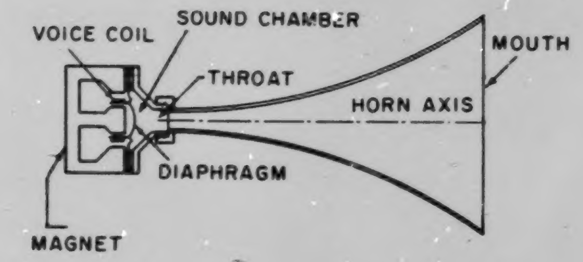
DIRECT RADIATOR LOUDSPEAKER.—The direct radiator loudspeaker, sometimes called a CONE LOUDSPEAKER, is the simplest form of sound loudspeaker. In this type of loudspeaker (fig. 8-5), the diaphragm acts directly on the medium, which is air. Both sides of the diaphragm are open to the air so that sound is radiated behind as well as in front of the loudspeaker. At the instant the diaphragm is moving in an outward direction, a compression wave is produced by the front surface of the diaphragm and a rarefaction wave is produced by the back surface of the diaphragm.

At low frequencies, where the wavelength is large compared with the dimensions of the loudspeaker, the rarefaction wave from the back of the diaphragm meets the compression wave from the front of the diaphragm and neutralizes it because the waves are in opposite phase relation. Thus low frequencies are not reproduced from this type of direct radiator.

At higher frequencies, where the wavelength of the sound is small compared with the dimensions of the loudspeaker, the sound waves from the front of the diaphragm have time to travel an appreciable distance away from the loudspeaker (in terms of wavelength) and the phase of vibration of the diaphragm changes before the interfering wave from behind can traverse the distance around the diaphragm. Hence, a BAFFLE is necessary only to reproduce low frequencies from a direct radiator. The purpose of the baffle is to delay the meeting of the front and back waves by artifically increasing the distance of the sound-wave path from the front to the back of the diaphragm.

The simplest form of baffle is a flat board with a hole in the center to accommodate the loudspeaker. This type of baffle is effective down to a frequency the wavelength of which is approximately four times the diameter of the baffle. If the loudspeaker is mounted in a wall or is completely enclosed, the baffle is called an INFINITE BAFFLE. When a cabinet is used as a baffle, it is desirable to line the inside with a sound-absorbing material to minimize the effect of cabinet resonances produced by standing waves within the enclosure.

HORN LOUDSPEAKER.—The use of the direct radiator loudspeaker is limited because of its low radiation efficiency. When it is necessary to produce high sound intensities or to cover large areas with sound, the radiation efficiency of the loudspeaker must be increased to keep the size of the amplifier within reasonable limits. Horns with appropriate driver units provide a practical solution to the problem. A horn may be considered as an impedance matching device for coupling a relatively heavy vibrating surface at the horn throat to a relatively light medium (the air), at the mouth of the horn. A STRAIGHT-HORN LOUDSPEAKER is shown in figure 8-6.

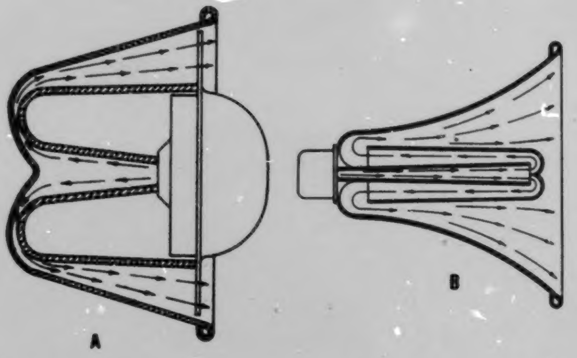


7.16.1
Figure 8-6.—Straight-horn loudspeaker.

For a horn to operate effectively, the mouth must be sufficiently large in comparison with the longest wavelength (lowest frequency) of sound that is to be transmitted. Low-frequency horns often are considered to be useful at frequencies above that for which the mouth diameter is about one-third wavelength. The performance of a horn loudspeaker near the low-frequency cutoff point depends to a great extent upon the flare or shape of the horn. The function of the horn contour is to produce a smooth and continuous increase in cross-sectional area in progressing from the small throat to the large mouth. The shape most commonly employed is the exponential horn in which the diameter increases progressively by a fixed percentage for each equal-distance increment along the horn axis. In order for the horn to be of a practical size and shape, a FOLDED-HORN LOUDSPEAKER is employed (fig. 8-7) in perference to a straight horn (fig. 8-6). There is a practical limit to the amount of power that can be handled by a conventional driver unit. When extremely high sound intensities must be produced, multiunit loudspeakers are employed in which the units are coupled to individual horn sections that are combined mechanically into a common loudspeaker assembly.

CHARACTERISTICS OF LOUDSPEAKERS

FREQUENCY RESPONSE.—In the majority of cases the frequency response of the loudspeaker is the limiting factor in the overall response of a sound system. For direct radiators the low frequency response is influenced by the (1) baffle or enclosure, (2) diameter of the cone, (3) ability of the cone and voice coil to execute large amplitudes of vibration, and (4) strength of the magnetic field in the air gap. The high-frequency response is limited by the mass of the voice coil and diaphragm.



7.16.2
Figure 8-7.—Folded-horn loudspeaker.

For horn loudspeakers, the low frequency response is influeneced principally by the (1) basic horn formula employed, (2) flare, and (3) mouth dimensions. The high frequency response is limited by the (1) mass of the voice coil and the diaphragm, (2) phase effects caused by differences in path lengths due to bends, and (3) impedance irregularities caused by sudden changes in cross-sectional areas at folds or joints in the horn. Vibrations of the horn walls must be sufficiently damped to avoid introducing irregularities into the response as well as transient effects.

DIRECTIVITY.—The directivity of a loudspeaker is an important factor in determining the efficiency of the sound radiation over the listening area. All practical forms of sound radiators exhibit some directional effects. If a radiator is placed in free space where the results are not affected by interfering reflections, the sound pressure at a given distance is not the same in all directions. The directivity of a loudspeaker is a function of both frequency and the size of the horn mouth of the loudspeaker. Thus, a loudspeaker becomes more directional with increasing frequency because of the shorter wavelength and a direct radiator or horn mouth of large size is more directional than one of smaller size. These factors of frequency and size are interrelated in that the size becomes a factor relative to the wavelength of the sound being transmitted. Thus the directional pattern of a small loudspeaker transmitting a high-frequency signal (short wavlength) is similar to that of a large loudspeaker transmitting a low-frequency signal (long wavelength). In general a horn loudspeaker of a given mouth diameter is more directional than a direct radiator of the same diameter, particularly at the lower frequencies.

The directivity of a horn loudspeaker is also dependent upon the rate of flare—that is, the directivity increases as the flare is made more gradual (longer horn). If a rectangular horn having a long narrow mouth (in terms of wavelength) is mounted with the long dimension of the mouth vertical, the radiation in the horizontal plane corresponds to that of a small radiator with a broad distribution pattern. The radiation in the vertical plane acts as a large radiator with a relatively narrow beam. In other words, the horn is made relatively much less directional in the horizontal plane than in the vertical plane. It is obvious that the reverse is true if the horn is turned so that the long dimension of the mouth is horizontal. Thus the sound energy is flattened out in a plane at right angles to the long dimension of the loudspeaker mouth. This principle is used to obtain the required directional characteristics for efficient high-intensity reproduction on the flight decks of aircraft carriers.

CAPACITY.—The load-carrying capacity of a loudspeaker is usually expressed in terms of the maximum electrical power that should be applied to it. This power is limited by heating, mechanical strength, and the production of nonlinear distortion which is caused by excessive diaphragm amplitudes or excessive acoustical pressures in the sound passages. Excessive power causes the diaphragm to strike portions of the magnet or supporting frame and may produce buzzing or rattling.

EFFICIENCY.—The loudness of the sound obtainable from a loudspeaker at any particular listening point is not a factor of load-carrying capacity alone. Other important factors are the efficiency and the amount that the sound is spread out. The definition of absolute efficiency of a loudspeaker is not subject to simple practical interpretation. However, for specification purposes and for checking the performance of naval loudspeakers, a specified voltage is applied to the input terminals and the output sound pressure is measured at a given distance from the loudspeaker on the loudspeaker axis using various test frequency signals. These measurements are combined with off-axis sound pressure measurements to evaluate the relative loudspeaker efficiency.

When satisfactory frequency in a loudspeaker is limited to a small angle about the axis, the absolute efficiency at high frequencies is considerably lower than at low frequencies. The use of diffusing arrangements with these loudspeakers to spread out the high frequencies usually results in spreading out the small amounts of available high-frequency energy to such an extent that the response is unsatisfactory at all locations.

IMPEDANCE.—The impedance of a loudspeaker is usually measured between the voice coil terminals at some average frequency, such as 1,000 hertz, in the usable range. This impedance varies with the frequency, rising with increasing frequency. The usual value of voice coil impedance varies from 3 to 15 ohms.

In shipboard announcing and public-address systems, a matching transformer is built into each loudspeaker to transform the low voice-coil impedance to a higher value suitable for connection to loudspeaker distribution lines. Because loudspeakers in a system are connected and operated in parallel, the combined impedance of a large number of low-impedance voice coils without matching transformers would be so low compared with the resistance of the connecting cables that an appreciable portion of the amplifier output power would be dissipated in the cables. Thus matching transformers are provided to reduce this loss. These transformers have several taps in order to vary the loudspeaker impedance. Changing the loudspeaker impedance changes the power absorbed by the loudspeaker from the lines and thus provides a means of varying the loudness of the loudspeaker.

ANNOUNCING SYSTEMS

Shipboard announcing and intercommunicating systems, circuits 1MC through 54MC, serve the general purpose of transmitting orders and information between stations within the ship by amplified voice communication. This function is accomplished by (1) a central amplifier system, when it is desired to broadcast orders or information simultaneously to a number of stations or by (2) an intercommunicating system

Table 8-1.—Shipboard Announcing Systems

Circuit	System	Importance	Readiness Class
*IMC	General	V	1
*2MC	Propulsion plant	V	1
*3MC	Aviators'	V	1
4MC	Damage Control	V	1
*5MC	Flight Deck	SV	2
*6MC	Intership	SV	1
7MC	Submarine Control	V	1
8MC	Troop administration and control	SV	2
*9MC	Underwater troop communication	SV	2
*10MC	Dock Control (obsolete)	SV	1
*11-16MC	Turret (obsolesce[illegible]	SV	3
*17MC	Double Purpose Battery (obsolescent)	SV	3
18MC	Bridge	NV	2
19MC	Aviation Control	SV	2
*20MC	Combat Information (obsolescent)	SV	1
21MC	Captain's Command	SV	1
22MC	Electronic Control	NV	1
23MC	Electrical control	SV	1
24MC	Flag Command	SV	1
25MC	Ward Room (obsolescent)	NV	4
26MC	Machinery Control	SV	1
27MC	Sonar and Radar Control	SV	1
*28MC	Squadron (obsolescent)	NV	4
*29MC	Sonar Control and Information	SV	2
30MC	Special Weapons	SV	2
31MC	Escape trunk	SV	2
32MC	Weapons control	SV	3
33MC	Gunnery Control (obsolescent)	SV	3
34MC	Lifeboat (obsolescent)	SV	1
35MC	Launcher Captains'	SV	1
36MC	Cable Control (obsolete)	NV	4
37MC	Special Navigation (osbolete)	SV	2
38MC	Electrical (obsolete)	NV	1
39MC	Cargo Handling	NV	4
40MC	Flag Administrative	NV	1
41MC	Missile Control and Announce (obsolete)	SV	3
42MC	CIC Coordinating	SV	2
43MC	Unassigned		
44MC	Instrumentation Space	NV	1
45MC	Research operations	NV	1
*46MC	Aviation Ordnance and Missile Handling	SV	2
47MC	Torpedo Control	SV	2
48MC	Stores conveyor (obsolescent)	NV	1
49MC	Unassigned		
50MC	Integrated operational intelligence center	SV	2

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Table 8-1.—Shipboard Announcing Systems—Continued

Circuit	System	Importance	Readiness Class
51MC	Aircraft Maintenance and handling control	SV	2
52MC	Unassigned		
53MC	Ship Administrative	NV	4
54MC	Repair officer's control	NV	4
55MC	Sonar Service	NV	4
56MC	Unassigned		
57MC	Unassigned		
58MC	Hanger Deck Damage Control	V	1
59MC	SAMID Alert	SV	3

* - Central amplifier systems.

27.123.0

when it is desired to provide two-way transmission of orders or information.

Each announcing and intercommunicating system installed aboard ship is assigned an IC circuit designation in the MC series. The Chief of Naval Operations authorizes these MC circuits for each class of vessel, based on size, complement, function, and operational employment. Authorized IC announcing circuits are listed in Table 8-1, according to important and readiness. These systems, however, are not all installed in any one ship.

For general announcing, circuit 1MC is installed in all surface ships above 180 feet in length, except aircraft carriers, amphibious ships fitted with flight decks, and large combatant ships. Aircraft carriers, amphibious ships fitted with flight decks, and large combatant ships are provided with circuits 1MC and 3MC.

CENTRAL AMPLIFIER ANNOUNCING SYSTEM

The central amplifier announcing system is designed to furnish amplified voice communications and alarm signals to the various loudspeaker groups aboard ship. The system provides for transmitting the spoken word or signal at any one of several stations, amplifying this signal at a central amplifier, and radiating the signal from a number of loudspeakers.

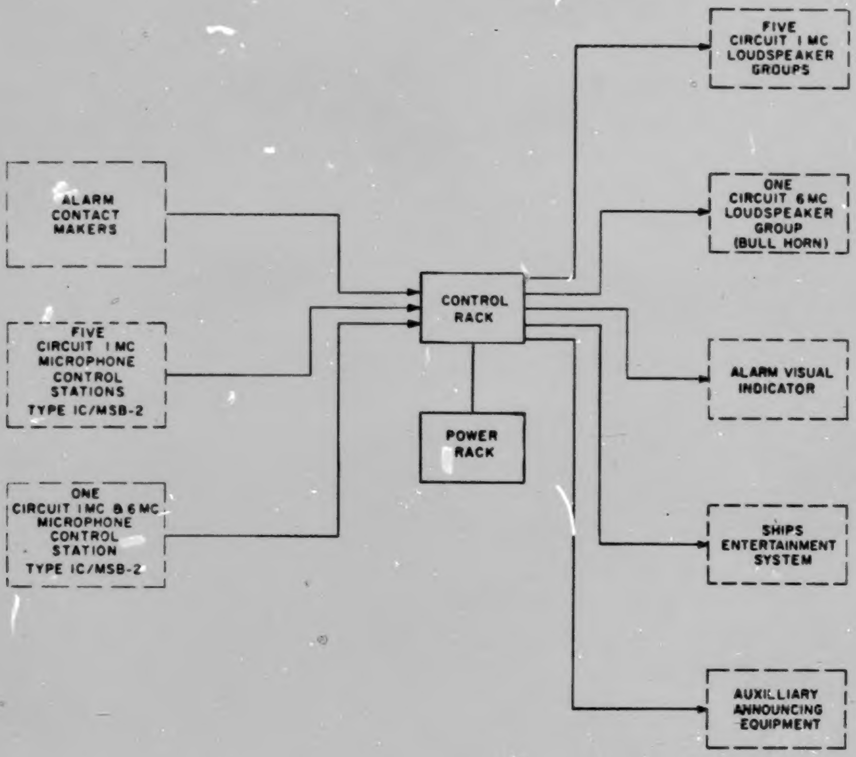
The components of a representative system on a cruiser are block diagrammed in figure 8-8. The system consists of audio amplifier equipment to provide circuit 1MC functions for general announcing, and circuit 6MC functions for intership announcing. Power for operating the equipment is obtained from the ship's single-phase 115-volt power supply.

ALARM CONTACT MAKERS

Alarm contact makers are located at various points in the ship. The closure of an alarm contact maker will sound any one of four alarm signals over all circuit 1MC loudspeakers. Alarm signals are not transmitted over circuit 6MC. The alarm signals in the order of their priority are: (1) collision, (2) chemical attack, (3) general, and (4) sonar. The order of priority is controlled automatically by relays in the audio amplifier cabinet. Any alarm takes priority over voice announcements.

If an alarm is being sounded and a higher priority alarm contact maker is closed, relays in the audio amplifier cabinet operate to cut off the alarm signal being sounded and cause the higher priority alarm to be sounded instead. Conversely, the closure of a low priority alarm contact maker has no effect on a high priority alarm that is being sounded.

The oscillator operates to generate the alarm signals as long as the alarm contact maker is held closed (except for general alarm which is sounded for a predetermined 15-second interval after momentary closure of the general alarm contact maker). Release


FIVE CIRCUIT 1MC LOUDSPEAKER GROUPS
ONE CIRCUIT 6MC LOUDSPEAKER GROUP (BULL HORN)
ALARM CONTACT MAKERS
CONTROL RACK
FIVE CIRCUIT 1MC MICROPHONE CONTROL STATIONS TYPE IC/MSB-2
ALARM VISUAL INDICATOR
POWER RACK
ONE CIRCUIT 1MC & 6MC MICROPHONE CONTROL STATION TYPE IC/MSB-2
SHIPS ENTERTAINMENT SYSTEM
AUXILIARY ANNOUNCING EQUIPMENT

140.125

Figure 8-8.—1MC-6MC Equipment—block diagram.

of the alarm contact maker causes the equipment to be returned to STANDBY after sounding the alarm. The visual alarm circuit is closed continuously during a chemical attack alarm, and intermittently during a general alarm.

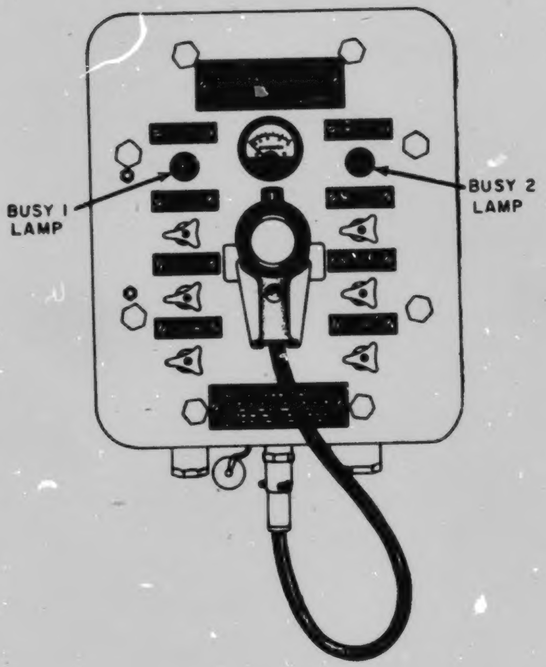
CENTRAL AMPLIFIER SYSTEM

Four microphone control stations are located at various points throughout the ship. The circuit 1MC-6MC microphone control station can select any one or more of the four 1MC loudspeaker groups or the circuit 6MC loudspeakers. The other microphone control stations are wired to permit the selection of circuit 1MC loudspeaker groups only. The operation of circuit 1MC from any microphone control station has priority over circuit 6MC operation. Microphone control stations on circuit 1MC do not have priority over each other, however, the bridge station does have priority over all others.

When the press-to-talk switch on the microphone of any microphone control station is operated for general voice announcements (fig. 8-9), all loudspeakers selected at this control station (except the loudspeaker in the immediate area of the control station in use) are connected to the equipment and reproduce the message spoken into the microphone. It is possible for the 1MC-6MC microphone control station to transmit over circuit 6MC loudspeakers at the same time that a circuit 1MC microphone control station is transmitting over a circuit 1MC loudspeaker group.

LOUDSPEAKER GROUPS

The loudspeakers associated with circuit 1MC operation are divided into four groups designated



7.19

Figure 8-9.—Microphone control station.

(1) officers, (2) topside, (3) crew, and (4) engineers. There is only one circuit 6MC loudspeaker group.

AUDIO AMPLIFIER CABINET

The control circuits for circuit 1MC and circuit 6MC are contained in the audio amplifier cabinet (fig. 8-10). In addition to the various relays, indicator lamps, fuses, transfer switches, and test switches, the cabinet contains two oscillator assemblies, two preamplifier assemblies, and two power amplifier assemblies.

The oscillators, one of which is a spare, are used to generate the alarm signals. The preamplifiers are used to increase the microphone output on voice signals to a level sufficiently high to drive the power amplifiers. The power amplifiers are used to increase the level of the alarm signals from one of the oscillators and the voice signals from one of the preamplifiers for reproduction by the loudspeakers.

Two identical amplifier channels are provided to permit the operation of the 1MC and 6MC circuits independently on the two channels (fig. 8-11). Each channel includes a preamplifier and a power amplifier. Channel selection is accomplished by means of the amplifier channel selector switch on the audio amplifier cabinet.

Normal operation of the system is obtained with the amplifier channel selector switch set at 1MC on A and 6MC on B. When the switch is set at 1MC-6MC on A, channel B is isolated for troubleshooting and repair, and the announcements and alarm signals are transmitted on channel A. Conversely, when the switch is set at 1MC-6MC on B, channel A is isolated and all transmission is over channel B.

Preamplifiers

The preamplifiers consists of a power supply, three parallel-connected voltage amplifier stages, a push-pull-parallel connected power amplifier stage, a limiter circuit, and a compressor circuit.

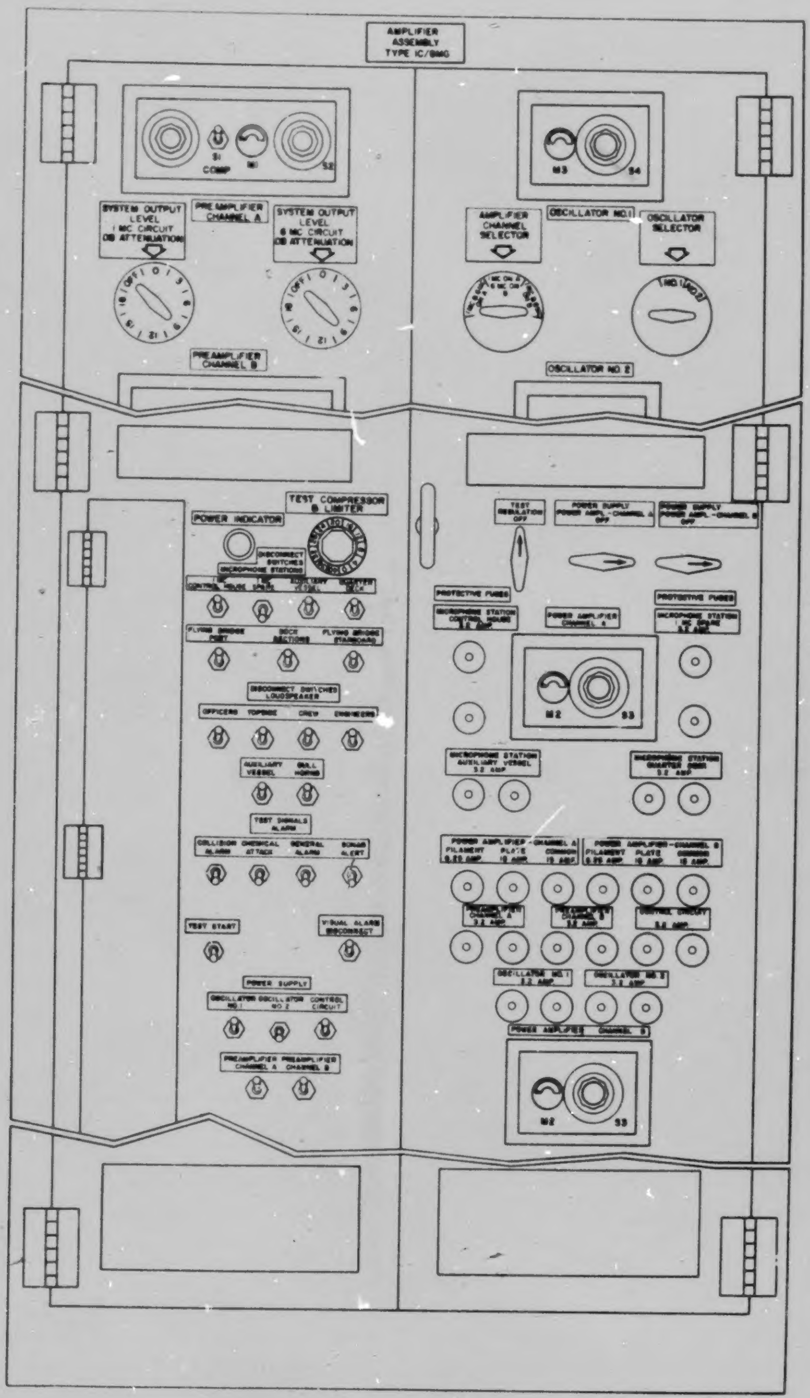
The COMPRESSOR circuit provides greater amplifier gain with low-level signals than with high-level signals, thus compensating for the differences in voice inputs at the microphone control stations. When the compressor switch, S1 (fig. 8-10) is in the ON position, the bias of the first stage voltage amplifier is reduced, resulting in a 14 db maximum increase in amplifier gain for low-level input signals. The LIMITER circuit provides for a rapid reduction in amplifier gain when the amplitude of the input signal would overload the amplifier and cause distortion.

The compressor-limiter circuit consists of twin triodes, operating as a phase-inverter and limiter.

Normal operation of the preamplifier can be checked by measuring the overall output and plate current of each stage by the meter, M1, and meter switch S2. The meter switching is arranged so that normal operation of each stage is indicated by a midscale meter reading of 0 db ± 2 db.

Power Amplifiers

The power amplifiers consist of a voltage amplifier stage, a phase inverter stage, two driver stages, and a final power amplifier stage. Two tubes (not sections) operate in parallel for every stage except the final stage which has two groups of three triodes in parallel and the


AMPLIFIER ASSEMBLY TYPE IC/BMG
S1 COMP
M1
S2
SYSTEM OUTPUT LEVEL 1 MC CIRCUIT DB ATTENUATION
PREAMPLIFIER CHANNEL A
SYSTEM OUTPUT LEVEL 6 MC CIRCUIT DB ATTENUATION
OFF 0 3 6 9 12 15 18
PREAMPLIFIER CHANNEL B
M3
S4
AMPLIFIER CHANNEL SELECTOR
OSCILLATOR NO.1
OSCILLATOR SELECTOR
NO.1 NO.2
OSCILLATOR NO. 2
TEST COMPRESSOR & LIMITER
POWER INDICATOR
DISCONNECT SWITCHES MICROPHONE STATIONS
FLYING BRIDGE PORT
DECK SECTIONS
FLYING BRIDGE STARBOARD
DISCONNECT SWITCHES LOUDSPEAKER
OFFICERS
TOPSIDE
CREW
ENGINEERS
AUXILIARY VESSEL
BULL HORNS
TEST SIGNALS ALARM
COLLISION ALARM
CHEMICAL ATTACK
GENERAL ALARM
SONAR ALERT
TEST START
VISUAL ALARM DISCONNECT
POWER SUPPLY
OSCILLATOR NO 1
OSCILLATOR NO 2
CONTROL CIRCUIT
PREAMPLIFIER CHANNEL A
PREAMPLIFIER CHANNEL B
TEST REGULATION OFF
POWER SUPPLY POWER AMPL.-CHANNEL A OFF
POWER SUPPLY POWER AMPL.-CHANNEL B OFF
PROTECTIVE FUSES
MICROPHONE STATION CONTROL HOUSE 3.2 AMP
POWER AMPLIFIER CHANNEL A
PROTECTIVE FUSES
MICROPHONE STATION 1 MC SPARE 3.2 AMP
M2
S3
MICROPHONE STATION AUXILIARY VESSEL 3.2 AMP
MICROPHONE STATION QUARTER DECK 3.2 AMP
POWER AMPLIFIER-CHANNEL A FILAMENT 0.25 AMP PLATE 10 AMP COMMON 10 AMP
POWER AMPLIFIER-CHANNEL B FILAMENT 0.25 AMP PLATE 10 AMP COMMON 10 AMP
PREAMPLIFIER CHANNEL A 3.2 AMP
PREAMPLIFIER CHANNEL B 3.2 AMP
CONTROL CIRCUIT 3.2 AMP
OSCILLATOR NO.1 3.2 AMP
OSCILLATOR NO.2 3.2 AMP
POWER AMPLIFIER CHANNEL B
M2
S3

7.20

Figure 8-10.—Audio amplifier cabinet.

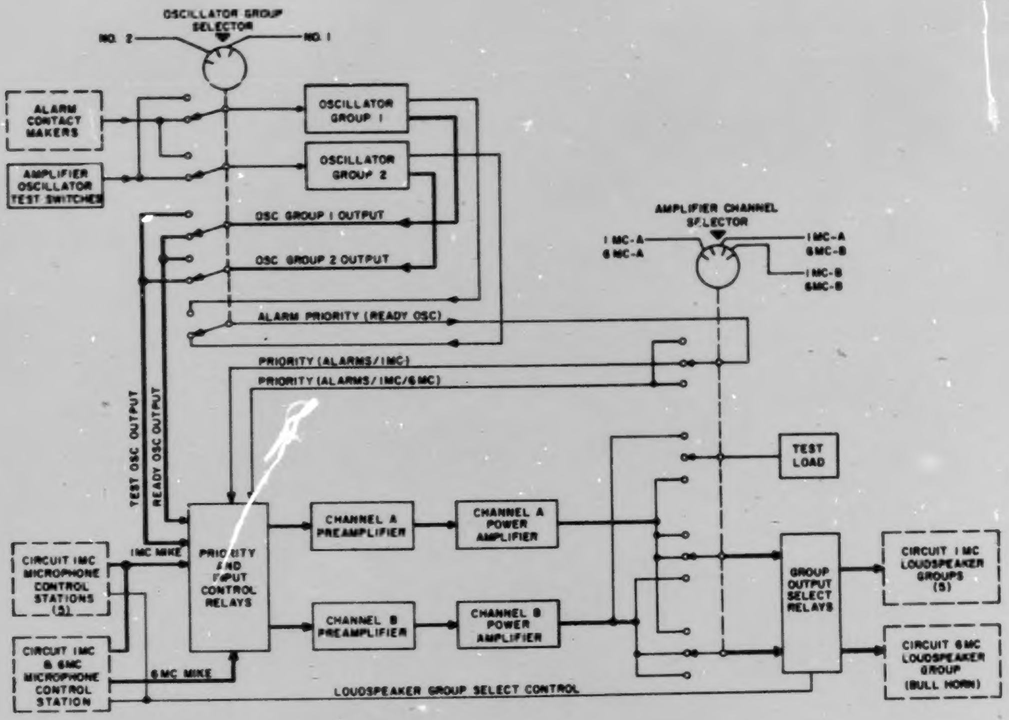

OSCILLATOR GROUP SELECTOR
NO. 2
NO. 1
ALARM CONTACT MAKERS
AMPLIFIER OSCILLATOR TEST SWITCHES
OSCILLATOR GROUP 1
OSCILLATOR GROUP 2
OSC GROUP 1 OUTPUT
OSC GROUP 2 OUTPUT
ALARM PRIORITY (READY OSC)
PRIORITY (ALARMS/1MC)
PRIORITY (ALARMS/1MC/6MC)
AMPLIFIER CHANNEL SELECTOR
1MC-A
6MC-A
1MC-A
6MC-B
1MC-B
6MC-B
TEST OSC OUTPUT
READY OSC OUTPUT
TEST LOAD
CIRCUIT 1MC MICROPHONE CONTROL STATIONS (5)
1MC MIKE
PRIORITY AND INPUT CONTROL RELAYS
CHANNEL A PREAMPLIFIER
CHANNEL A POWER AMPLIFIER
CHANNEL B PREAMPLIFIER
CHANNEL B POWER AMPLIFIER
GROUP OUTPUT SELECT RELAYS
CIRCUIT 1MC LOUDSPEAKER GROUPS (5)
CIRCUIT 6MC LOUDSPEAKER GROUP (BULL HORN)
CIRCUIT 1MC & 6MC MICROPHONE CONTROL STATION
6MC MIKE
LOUDSPEAKER GROUP SELECT CONTROL

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Figure 8-11.—Simplified system switching diagram.

two groups in push-pull. The parallel connection of the triodes permits circuit operation in the event of failure or removal of one tube per stage (two tubes in the final stage).

The power to operate the power amplifier is supplied through a 3-conductor polarized plug, directly to the filament transformer, and through switch S3 (fig. 8-10) to the plate power, transformer. A time-delay relay (not shown), external to the amplifier chassis, prevents the application of power to the plate power transformer until approximately 30 seconds after filament power has been applied.

The operation of each stage of the power amplifier in addition to the overall audio output chan be checked by meter M2 and the 7-position meter switch, S3 (fig. 8-10). Normal operation of each stage is indicated by a midscale reading on the meter with rated input signal and output load.

Oscillators

Each oscillator is capable of generating a variety of alarm signals although only four are used in this application: (1) collision, (2) chemical attack, (3) general, and (4) sonar. Each oscillator is also capable of generating four additional alarm signals which can be used in the event of future expansion of the system. The additional alarms are (1) simulated motor-operated horn type signal; (2) jump-tone signal which alternates between 600 and 1,000 Hz at the rate of 1 1/2 Hz; (3) jump-tone signal which alternates between 600 and 1,500 Hz at the rate of 6 Hz; and (4) simulated siren type signal. However, these alarms are not discussed in this chapter.

When any alarm is sounded, the frequency of relay operations is similar except that relays associated with the particular alarm are energized. The function of each individual relay in the system is explained in the applicable manufacturer's technical manual furnished with the equipment. The operation of the oscillator for the various alarms is based on the system being set up for normal operation using oscillator 1 and channel A for 1MC and channel B for circuit 6MC.

The oscillator generates the alarm signals as long as the alarm contact maker is held closed (except for general alarm which is sounded for a predetermined 15-second interval after momentary closure of the general alarm contact maker). Release of the alarm contact maker causes the equipment to be returned to STANDBY after sounding the alarm. The visual alarm circuit is closed continuously during a chemical attack alarm, and intermittently during a general alarm.

Closure of any collision alarm contact maker energizes relays in the audio amplifier cabinet, which in turn energizes the collision alarm contactor associated with the oscillator in active service to pulse the signal output of the oscillator and produce the collision alarm.

The COLLISION ALARM is a pulsed 1000 Hz signal. Each cycle of the signal consists of three pulses of 0.06 second and the third pulse is followed by an off period of 0.3 second. This cycle is repeated continuously as long as the collision alarm contact maker is actuated.

The CHEMICAL ATTACK ALARM is a steady-tone signal of 1000 Hz. The closure of any chemical attack contact maker effectively completes the control power circuit to the relay associated with the chemical attack alarm, provided the relay associated with the collision alarm has not operated to establish a higher priority signal. The chemical attack signal is generated and amplified in the same manner as the collision alarm signal; however, the signal is not pulsed.

The GENERAL ALARM is a simulated single-stroke gong-tone striking at the rate of 90 strokes per minute. The tone is caused to delay between strokes in a natural manner and the signal strokes are repeated automatically for 15 seconds after the alarm has been started. The signal-duration and stroke-repetition rate are determined by timing relays and contactors (not shown) in the audio amplifier cabinet but external to the oscillator assembly.

The momentary closure of any general alarm contact maker completes the control power circuit to the relay for the general alarm provided the relays for the collision alarm and the chemical attack alarm have not operated to establish a higher priority signal.

The general alarm contactor determines (1) the duration (15 seconds) of the general alarm, and (2) the 90 strokes per minute striking rate of the gong tone. An additional switch on the oscillator contactor pulses the visual alarm (busy lights on the microphone control stations) in step with the general alarm signal.

The SONAR ALARM is a jump-tone signal alternating between 600 and 1500 Hz at the rate of 1 1/2 Hertz. The closure of any sonar alarm contact maker completes the control power circuit to the relay for the sonar alarm provided that other alarm relays have not operated to establish a higher priority signal.

Normal operation of an oscillator can be checked by measuring the plate current of the various stages and the overall output by meter M3 and meter switch S4 (fig. 8-10). The meter switching is arranged so that normal operation of each stage is indicated by a midscale meter reading.

OPERATION

The path of circuits 1MC and 6MC from the inputs to the loudspeakers is shown by the block diagram in figure 8-11. The selector switch for the oscillators and amplifiers is set for normal operation with oscillator 1 and both amplifiers in active use. Channel A is normally used for circuit 1MC and channel B for circuit 6MC. In case of failure of a preamplifier or power amplifier, both circuit 1MC and circuit 6MC can be switched for operation on either channel A or channel B. When both circuits, 1MC and 6MC, are switched to the same channel, circuit 1MC has priority over circuit 6MC operation.

Circuit 1MC Microphone Control Station

To make voice announcements from a circuit 1MC microphone control station, operate one or more of the loudspeaker group selector switches (fig. 8-9) to select the area or areas to receive the announcement. Observe the busy indicators.

When BUSY 1 lamp is lighted, circuit 1MC amplifier is in use. Except in an emergency, do not attempt to use circuit 1MC when BUSY lamp is lighted. If another microphone control station selects a circuit 1MC loudspeaker group and operates the press-to-talk switch, the transmission from both microphone control stations will go out to all loudspeaker groups selected by both microphone stations.

When BUSY 2 lamp is lighted, circuit 6MC amplifier is in use and will have no effect on circuit 1MC operation.

When both BUSY 1 and BUSY 2 lamps are lighted, (1) an alarm signal is being transmitted irrespective of the amplifier in use; (2) both circuit 1MC and circuit 6MC are in use, and if another microphone control station attempts to use circuit 1MC the transmission from both microphone stations will go out to all loudspeaker groups selected by both microphone stations; or (3) both circuit 1MC and circuit 6MC are on one amplifier (during test or in the event of failure of an amplifier channel) and one or the other circuit is in use.

Circuit 1MC takes priority over circuit 6MC, therefore, if circuit 6MC is in use and a circuit 1MC loudspeaker group is selected from another microphone control station, circuit 6MC will be cut off when the microphone press-to-talk switch is operated and the announcement will go out to the circuit 1MC loudspeakers only. If circuit 1MC is in use and a circuit 1MC loudspeaker group is selected, the transmission from both microphone stations will go out to all loudspeaker groups selected by both microphone stations.

Circuit 1MC-6MC Microphone Control Station

To make voice announcements from the 1MC-6MC microphone control station, operate the intership selector switch (fig. 8-9). Observe the busy indicators as previously described.

When the BUSY 1 lamp is lighted, circuit 1MC is in use, but circuit 6MC can be slected and used at the same time without interference to the transmission on circuit 1MC. Except in an emergency, do not attempt to use circuit 1MC when the BUSY 1 lamp is lighted. If a microphone control station selects a circuit 1MC loudspeaker group and operates the press-to-talk (microphone) switch when the BUSY 1 lamp is lighted, the transmission from both microphone stations will go out to all circuit 1MC loudspeaker groups selected by both microphone stations.

When both BUSY 1 and BUSY 2 lamps are lighted, (1) an alarm signal is being transmitted; or (2) both circuit 1MC and circuit 6MC are on one amplifier (during test or in the event of failure of an amplifier channel) and circuit 1MC is in use from another mikrophone control station. Because circuit 1MC has priority over circuit 6MC, it is not possible to use circuit 6MC when both the BUSY 1 and BUSY 2 lamps are lighted. If a circuit 1MC loudspeaker group is selected and the press-to-talk switch is operated, the transmission from both microphone control stations will go out to all circuit 1MC loudspeakers selected by both microphone stations.

Alarm Contact Maker

The operation of an alarm contact maker will take precedence over any microphone control station. When an alarm is sounded, the BUSY 1 and BUSY 2 indicators are lighted at all microphone control stations and the alarm signal is transmitted to all circuit 1MC loudspeakers. With the exception of the general alarm, the alarm signals will be sounded only as long as the contact maker is held in the operated position. The general alarm signal, once started by momentary operation of the general alarm contact maker, will continue for 15 seconds. This alarm can be repeated by again momentarily closing the general alarm contact maker.

Audio Amplifier Cabinet

Normal operation does not involve the operation or switching of controls at the audio amplifier cabinet, provided the switches and controls are set for norml operation. The meters on each oscillator and amplifier assembly can be observed for normal operation by placing the meter switch in position 1.

During the transmission from a microphone control station, normal operation of the preamplifier and power amplifier in active use is shown by a meter reading which swings to 0 db on voice peaks. During the transmission of alarm signals, normal operation of an oscillator in active service depends on the nature of the alarm signal. Normal operation of an oscillator on general alarm is indicated by a reading which swings from no reading to midscale (0 db). During alarm signals the preamplifier is bypassed. Normal operation of a power amplifier in active servce is indicated by a reading within ±2 db of the meter reading for the oscillator.

MAINTENANCE

The Planned Maintenance Subsystem is the key to good MC operation and should be scrupulously followed. Good preventive maintenance results in less corrective maintenance being required.

If the entire announcing system is inoperative, the trouble is probably in the ship's power supply or wiring from the ship's power supply. Check the power available indicator on the audio amplifier cabinet (fig. 8-10). This indicator, unless it is defective, will be lighted when power is available at the cabinet.

Check the fuses in the early stages of troubleshooting. All fuses are located on the control panel of the audio amplifier cabinet in combination fuse holders and blown-fuse indicators, and are accessible from the front of the cabinet. Failure of a fuse is indicated when the neon-glow lamp in the fuse-holder cap is lighted. The switch controlling power to the circuit (which a fuse protects), must be in the ON position for the glow lamp to give an indication of fuse failure. Also, in the case of fuses protecting microphone control stations, the microphone talk switch at the microphone station must be operated to give an indication of fuse failure.

Performance failure of the shipboard announcing equipment can be corrected most readily by first isolating the assembly at fault, then isolating the circuit of that assembly, and finally by isolating the particular part causing the trouble. Localization of trouble in the system will be comparatively simple because of the test facilities included in the equipment. Also, the use of duplicate oscillator, preamplifier, and power amplifier assemblies permits the testing or repair of one assembly while the other assembly remains in active service, thereby avoiding the necessity for shutting down the system. Trouble in an assembly can be localized readily by using the meter and meter switch included in each assembly (fig. 8-10). In most cases a faulty assembly or even the faulty stage of an assembly can be localized by these meters without resorting to extensive troubleshooting procedures.

Microphone Control Station

A short circuit in the wiring to a microphone control station or a defect in a microphone control station can, under certain circumstances, prevent normal operation from other microphone control stations. In the event of such trouble, operate the microphone station disconnect switch to the OFF position. If the location of the defective microphone station is not known, operate all microphone station disconnect switches on the audio amplifier cabinet (fig. 8-10) to the OFF position, one at a time until the defective microphone control station is isolated. Leave this switch in the OFF position until the trouble has been corrected. Return all other microphone-station disconnect switches to the ON position.

Loudspeaker

A short circuit in a loudspeaker or in the loudspeaker wiring can cause a power amplifier, which tests normally, to act abnormally when switched into active service. It will result in a lower than normal meter reading of the power amplifier output. If the location of the defective wiring or loudspeaker is not known, operate the loudspeaker-group disconnect switches on the audio amplifier cabinet to the OFF position, one at a time until the defective loudspeaker group is isolated. This will be indicated by a return to normal meter reading (0 db ± 2 db) of the power amplifier.

If the trouble persists and is not in the microphone control stations or loudspeaker groups, it is probably in the preamplifier, power amplifier, or oscillator assembly.

Preamplifier

Normal output of a preamplifier is 10 volts which is indicated by a midscale reading of 0 db±db on the output meter with the meter transfer switch in position 1. Normal output is obtained from a preamplifier when the voice signals from a microphone control station are applied to the input terminals, or when attenuated alarm signals from an oscillator being tested (or being used as a source of test signal) are applied to the same terminals. In normal system operation, the alarm signals generated by an oscillator in active service bypass the preamplifier in active service and are applied directly to the input of the power amplifier in active service.

To check a preamplifier for normal operation, apply an attenuated signal from the oscillator not in active service to the input transformer of the preamplifier and observe the output meter readings from each meter switch position. Operate the test chemical attack alarm switch to the ON position (fig. 8-10) to cause the oscillator not in active service to generate a 1,000 Hz signal. This signal is attenuated and fed to the preamplifier on test through the test input control. The normal test signal input to the preamplifier will indicate a midscale reading of 0 db±2 db for the normal outputs of the various stages.

When the meter switch, S2, (fig. 8-10) is rotated to positions 1 through 7 inclusive, the output meter, M1, is connected to terminals in the various output stages of the preamplifier. If other than a normal reading is obtained, check the voltage of the stage or stages at fault and compare the readings with those listed in the applicable manufacturer's technical manual. Localize the trouble and replace the defective part.

Power Amplifier

Normal audio output of a power amplifier is 70 volts which is indicated by a reading of 0 db on the output meter with the meter switch in position 1 (fig. 8-12). In normal operation, alarm signals from the oscillator in active service drive the power amplifier to normal output. Likewise, the amplified voice signals from the preamplifier will drive a power amplifier to normal output.

During test, the oscillator not in active service is used to drive the preamplifier not in active service. The preamplifier, in turn, drives the power amplifier not in active service. The audio output of the power amplifier is fed to a dummy-load resistor combination in the secondary of the output transformer of the power amplifier. Switching arrangements in the audio amplifier cabinet prevent the test signals from reaching the loudspeakers.

In the majority of cases, trouble in any stage of the power amplifier will also affect the meter reading when measuring the output signal. Therefore, when an abnormal signal output is indicated on the meter, localize the trouble by using the power amplifier meter and meter switch to check the operation of all the stages.

To check a power amplifier for normal operation, operate the TEST START switch on the ON position (fig. 8-10) and observe the output meter readings from each meter switch position. The normal test signal input to the power amplifier should indicate a midscale reading of 0 db for normal audio output and a midscale meter reading of 0±2 db will indicate normal output for the other stages of the power amplifier.

When the meter switch, S3, is rotated to positions 1 through 7, inclusive, the output meter, M2, is connected to terminals in the various stages of the power amplifier. If an abnormal meter reading is indicated, check the voltage of the stage or stages at fault with the normal readings listed in the manufacturer's technical manual. Isolate the trouble and repair or replace the defective component.

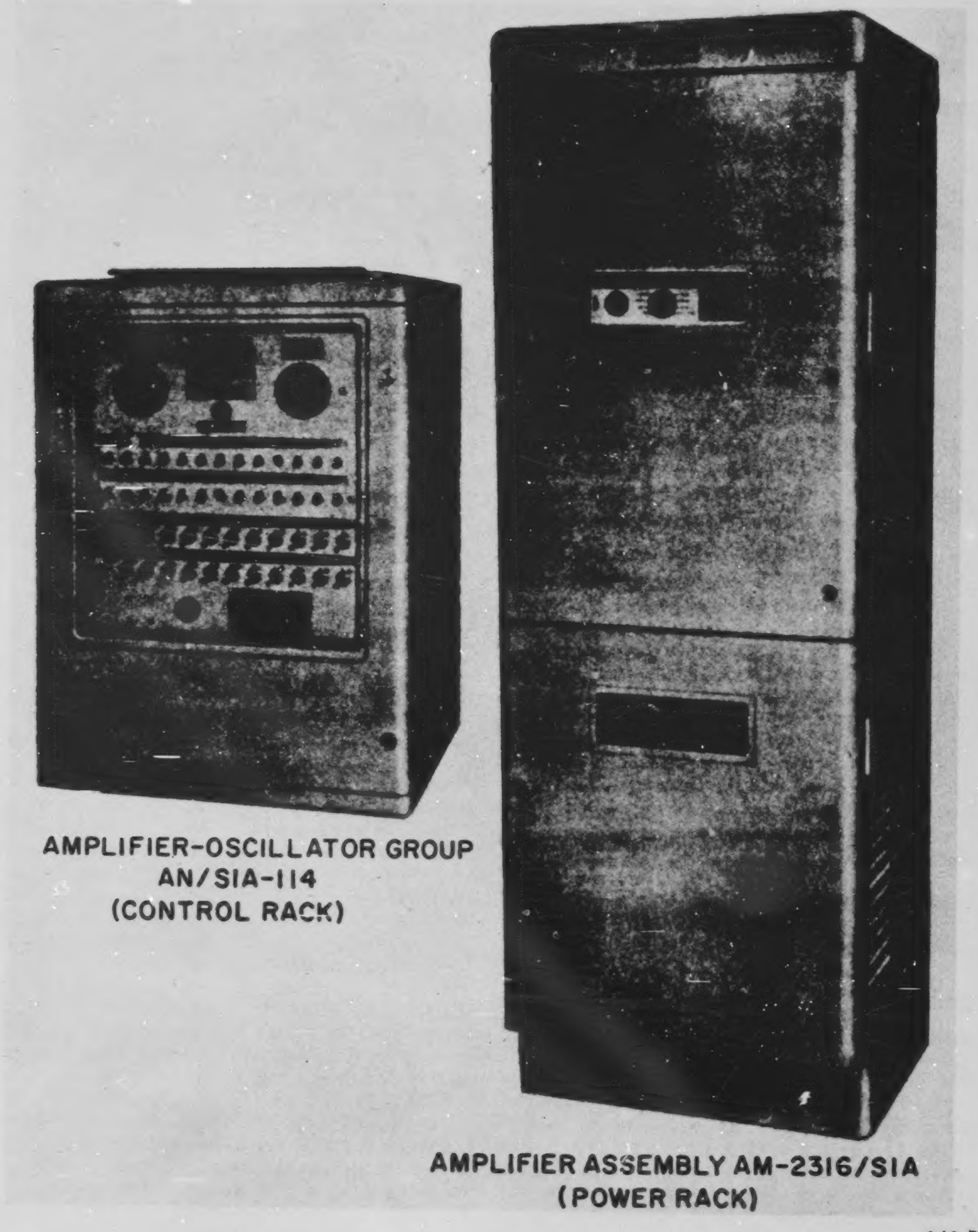
Oscillator

Normal output of an oscillator is 10 volts which is indicated by a midscale reading of 0 db with the meter switch in position 1 (fig. 8-10). On general alarm, collision alarm, and sonar alarm, this reading swings from no reading to 0 db. The 1,000 Hz test chemical attack alarm signal is used for adjusting the amplifier. It is essential that an output of 0 db be obtained from the oscillator.

Normal operation of each stage of an oscillator is indicated by the correct meter reading, when the meter, M3, is switched into each stage by meter switch, S4, and the various test alarm switches are operated. It is important to note that no reading will be obtained from some positions of the meter switch when alarms (test or actual) are being sounded. When troubleshooting an oscillator, be certain that a normal meter reading is not obtained for the particular stage before attempting to localize trouble within the stage. In most cases, trouble in one stage will also affect the meter reading when measuring the oscillator output with the meter switch in position 1.

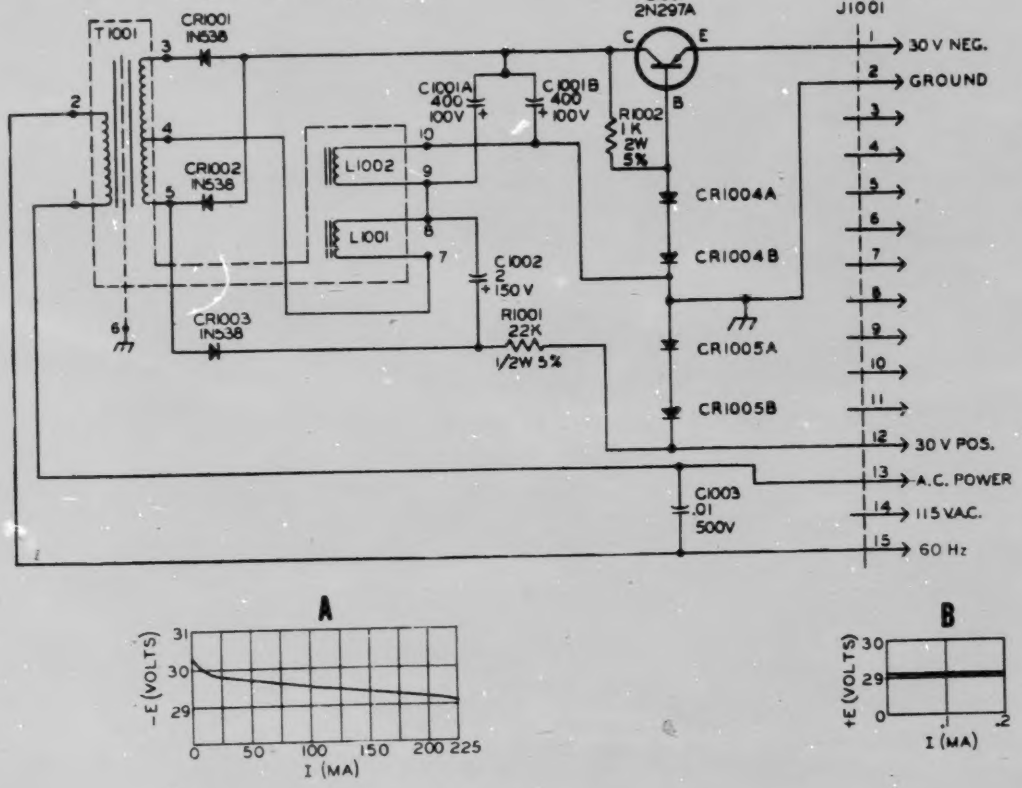
When an abnormal output is indicated, localize the faulty stage by checking the operation of each stage. Rotate the meter switch, S4, through its various positions and compare the readings of meter, M3, with the normal readings listed in the manufacturer's technical manual.

If any of these readings are above or below normal (0 db) by more than 2 db or if no reading is obtained, make a voltage test of the faulty stage or stages and compare the readings with the normal readings listed in the technical manual. Localize the trouble and repair or replace the faulty component as necessary.


AMPLIFIER-OSCILLATOR GROUP
AN/SIA-114
(CONTROL RACK)
AMPLIFIER ASSEMBLY AM-2316/SIA
(POWER RACK)

140.36

Figure 8-12.—1MC-6MC announcing system AN/SIA-114.


Q1001
2N297A
J1001
T1001
CR1001
1N538
CR1002
1N538
CR1003
1N538
C1001A
400
100V
C1001B
400
100V
R1002
1K
2W
5%
L1002
L1001
C1002
2
150V
R1001
22K
1/2W 5%
CR1004A
CR1004B
CR1005A
CR1005B
C1003
.01
500V
C
E
B
30 V NEG.
GROUND
30 V POS.
A.C. POWER
115 VAC.
60 Hz
A
-E (VOLTS)
I (MA)
B
+E (VOLTS)
I (MA)

140.37

Figure 8-13.—Power Supply pp-2563/SIA, schematic diagram.

1MC-6MC ANNOUNCING SYSTEM, AN/SIA-114

The 1MC-6MC announcing system, AN/SIA-114 is a later type of shipboard announcing system designed to perform the same functions as the system just discussed. The major units of the system are the control rack and the power rack, (fig. 8-12).

CONTROL RACK

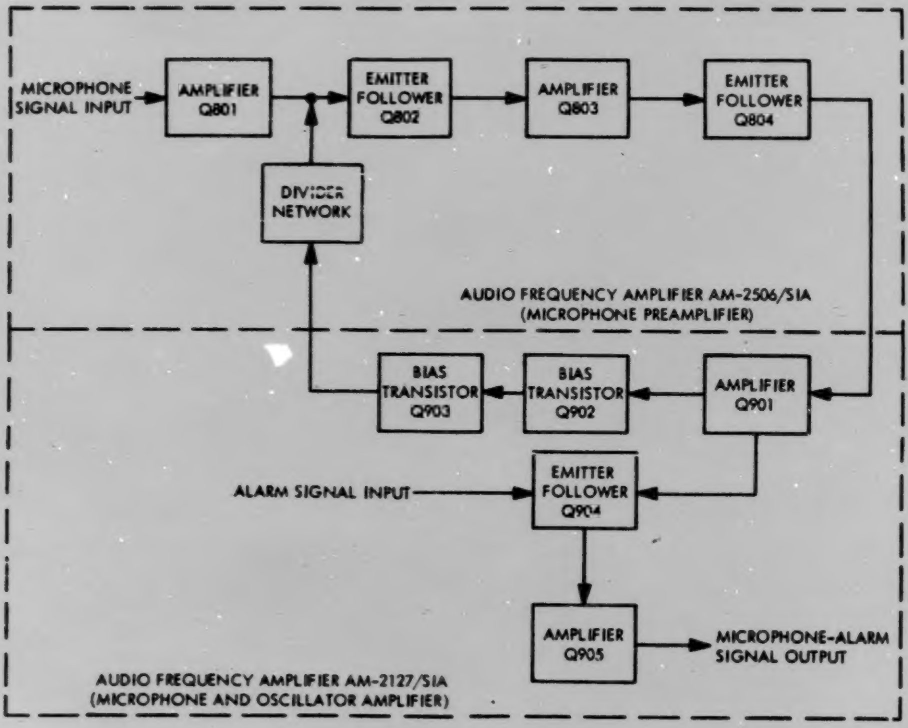
The control rack is a bulkhead mounted enclosure containing a control panel, two relay panel assemblies, a relay power supply, and sixteen plug-in assemblies, (eight for each channel).

The control panel mounts the various controls, switches, and indicators for system operation and testing. At the bottom of the control rack behind the front cover are two relay panels. The outer relay panel consists of 70 relays mounted in rectangular sockets, and the inner relay panel consists of 14 relays mounted in octal sockets. A relay power supply is mounted near the top of the inner relay panel.

The 8 plug-in assemblies for each channel consists of power supply, PP-2563/SIA; AF amplifiers, AM-2127/SIA, and AM-2506/SIA; and AF oscillators, 0-718/SIA, 0-721/SIA, 0-722/SIA, 0-724/SIA, and 0-725/SIA. A handle is provided on each plug-in assembly to facilitate removal and installation of the assembly.

Power Supply PP-2563/SIA

Transistorized power supply PP-2563/SIA (fig. 8-13), furnishes -30±2v.d.c. at 100 to 110


MICROPHONE SIGNAL INPUT
AMPLIFIER Q801
EMITTER FOLLOWER Q802
AMPLIFIER Q803
EMITTER FOLLOWER Q804
DIVIDER NETWORK
AUDIO FREQUENCY AMPLIFIER AM-2506/SIA (MICROPHONE PREAMPLIFIER)
BIAS TRANSISTOR Q903
BIAS TRANSISTOR Q902
AMPLIFIER Q901
ALARM SIGNAL INPUT
EMITTER FOLLOWER Q904
AMPLIFIER Q905
MICROPHONE-ALARM SIGNAL OUTPUT
AUDIO FREQUENCY AMPLIFIER AM-2127/SIA (MICROPHONE AND OSCILLATOR AMPLIFIER)

140.38

Figure 8-14.—Audiofrequency Amplifiers AM-2506/SIA and AM-2127/SIA block diagram.

ma, and +30±2 v.d.c. at .2 ma. The negative voltage is full-wave rectified, and the positive voltage is half-wave rectified.

Transmistor Q1001 and Zener diodes CR1004A and CR1004B regulate the -30-volt output as shown by curve A. Zener diodes CR1005A and CR1005B regulate the +30-volt output as shown by curve B.

AF Amplifier AM-2506/SIA

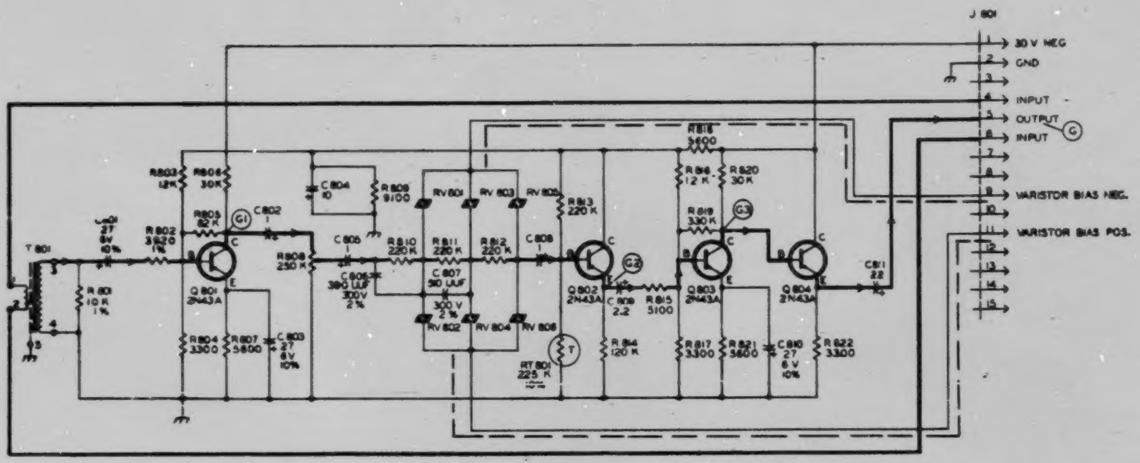
Audio-frequency amplifier AM-2506/SIA is a 4-transistor microphone preamplifier, the output of which drives a 5-transistor microphone and oscillator umplifier, AM-2127/SIA. See figure 8-14 for a block diagram.

The microphone preamplifier is a common emitter 4-stage amplifier with a divider network between the first and second stages, and a feedback circuit (which acts as a limiter circuit), via transistors Q902 and Q903 in the microphone and oscillator preamplifier.

AF Amplifier AM-2127/SIA

Audio-frequency amplifier AM-2127/SIA contains two transistor amplifier stages, Q901 and Q905, an emitter follower stage, Q904, and two bias transistors, Q902 and Q903, employed in a limiter circuit (fig. 8-14).

The limiter circuit consisting of Q902 and Q903, in conjunction with varistors RV801 through RV806 (fig. 8-15 and 8-16) provides signal amplitude control. Transistor Q902 is biased to conduct only on microphone input signals greater than the maximum amplitude limit. Conduction of Q902 results in conduction of Q903. Conduction of Q903 lowers the impedance of the network (dashed lines in fig. 8-15 and 8-16), resulting in a decrease in voltage across varistors RV801 through RV806. The voltage decrease on the varistors causes their resistance to increase, which reduces the Q802 base emitter bias current, and thus the gain of Q802.


J 801
30 V NEG
GND
INPUT
OUTPUT
G
INPUT
VARISTOR BIAS NEG.
VARISTOR BIAS POS.
T 801
R 801 10 K 1%
R 802 3920 1%
R 803 12K
R 806 30K
R 805 82 K
G1
C 802
Q 801 2N43A
R 804 3300
R 807 5600
C 803 27 6V 10%
C 804 10
R 809 9100
R 808 250 K
C 806
C 805 390 UUF 300V 2%
R 810 220 K
R 811 220 K
R 812 220 K
C 807 910 UUF 300 V 2%
RV 801
RV 802
RV 803
RV 804
RV 805
RV 806
C 808
R 813 220 K
RT 801 225 K
Q 802 2N43A
G2
C 809 2.2
R 814 120 K
R 815 5100
R 816 5600
R 818 12 K
R 820 30 K
R 819 330 K
G3
Q 803 2N43A
Q 804 2N43A
R 817 3300
R 821 5600
C 810 27 6 V 10%
R 822 3300
C 811 22

140.39

Figure 8-15.—AF amplifier AM-2506/SIA, schematic diagram.

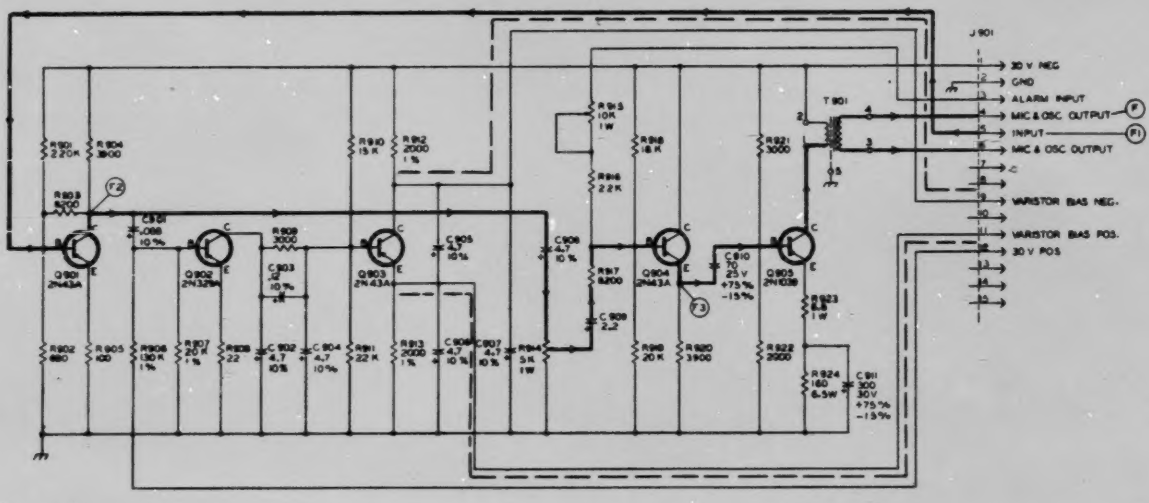
Alarm signals require less amplification than microphone signals and are therefore applied directly to the base of Q904.

AF Oscillator 0-718/SIA

Collision alarm oscillator 0-718/SIA contains a transistorized oscillator circuit which generates a pulsed 1000 hertz signal (fig. 8-17). Each period consists of three pulses, 50 milliseconds in duration. Each group of three pulses is followed by an off time of 0.35 second. This cycle is repeated continuously as long as power is applied to the circuit.

AF Oscillator 0-721/SIA

Chemical alarm oscillator 0-721/SIA contains a transistorized oscillator circuit which generates


J 901
30 V NEG
GND
ALARM INPUT
MIC & OSC OUTPUT
F
INPUT
F1
MIC & OSC OUTPUT
VARISTOR BIAS NEG.
VARISTOR BIAS POS.
30 V POS
T 901
R 901 220K
R 904 3900
R 903 8200
F2
C 901 .068 10%
Q 901 2N43A
Q 902 2N321A
R 909 3000
C 903 .1 10%
Q 903 2N43A
R 910 15 K
R 912 2000 1%
C 905 4.7 10%
C 906 4.7 10%
R 915 10K 1W
R 916 2.2K
R 917 8200
C 909 2.2
R 918 18 K
Q 904 2N43A
F3
C 910 70 25 V +75% -15%
R 921 3000
Q 905 2N1038
R 923 6.8 1W
R 924 160 6.5W
C 911 300 30V +75% -15%
R 902 680
R 905 100
R 906 130 K 1%
R 907 20 K 1%
R 908 22
C 902 4.7 10%
C 904 4.7 10%
R 911 22 K
R 913 2000 1%
C 908 4.7 10%
C 907 4.7 10%
R 914 5K 1W
R 919 20 K
R 920 3900
R 922 2000

140.40

Figure 8-16.—AF amplifier AM-2127/SIA, schematic diagram.

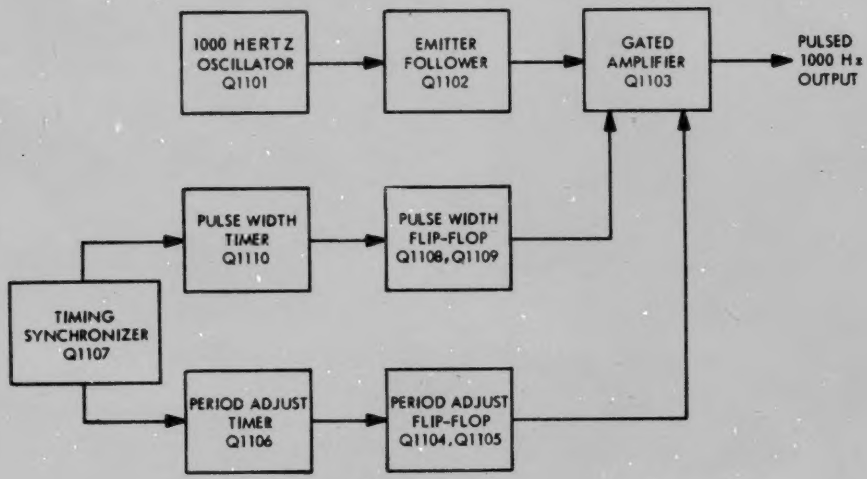
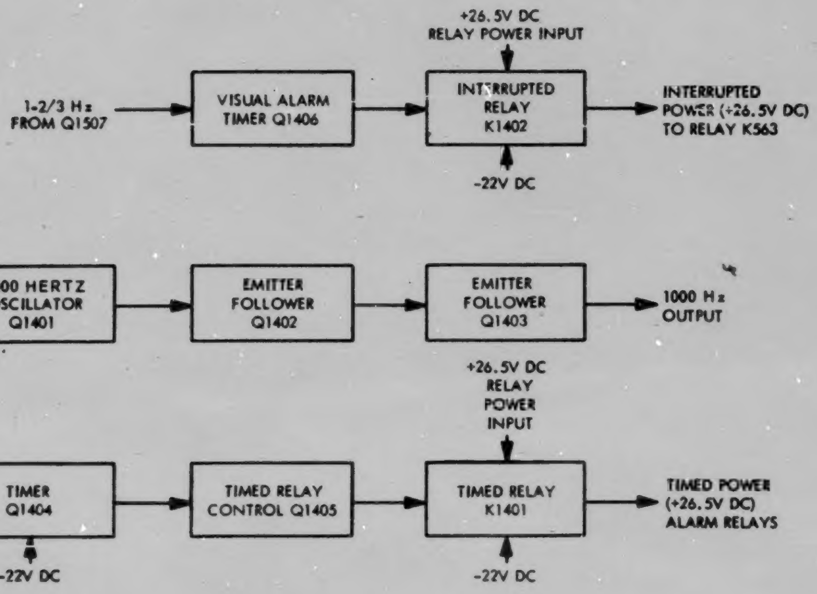

1000 HERTZ OSCILLATOR Q1101
EMITTER FOLLOWER Q1102
GATED AMPLIFIER Q1103
PULSED 1000 Hz OUTPUT
PULSE WIDTH TIMER Q1110
PULSE WIDTH FLIP-FLOP Q1108, Q1109
TIMING SYNCHRONIZER Q1107
PERIOD ADJUST TIMER Q1106
PERIOD ADJUST FLIP-FLOP Q1104, Q1105

Figure 8-17.—Audiofrequency oscillator 0-718/SIA (collision alarm), block diagram. 140.41

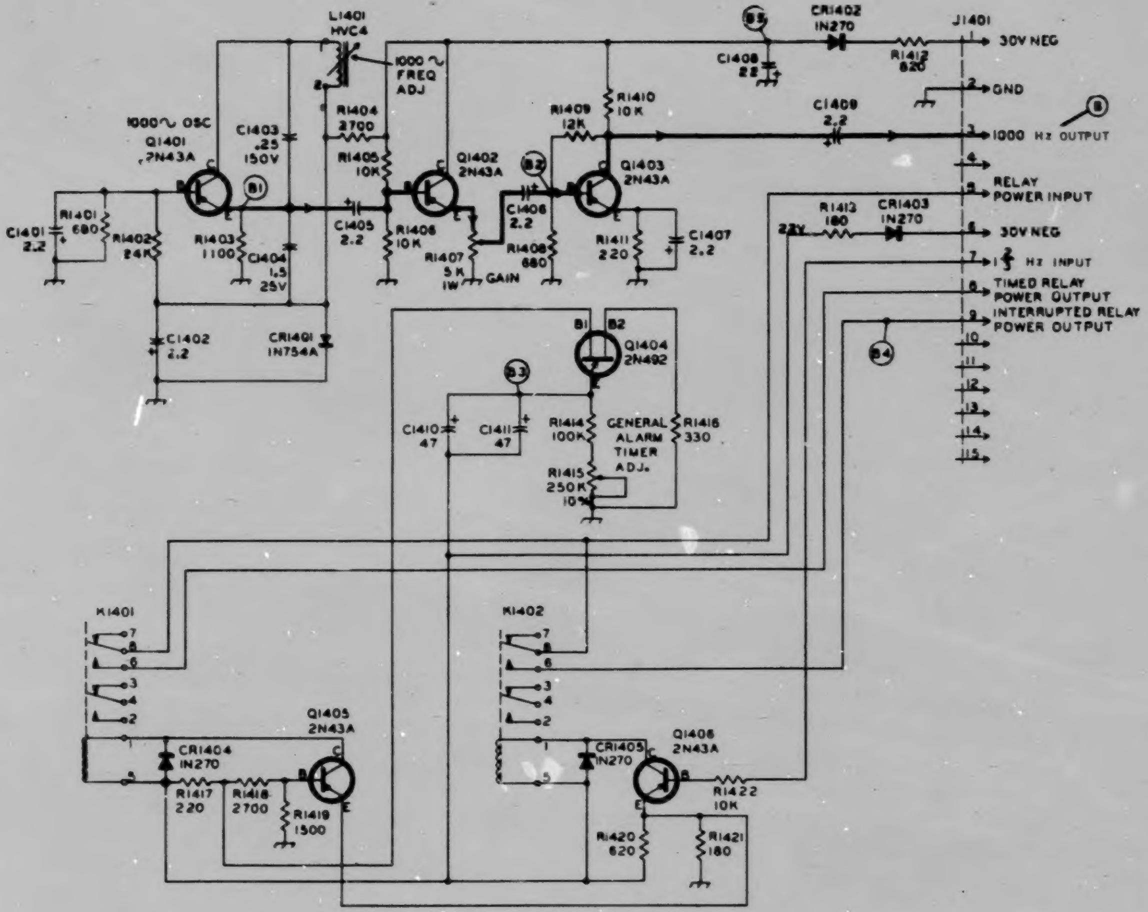
a continuous 1000 Hertz signal as long as power is applied to the circuit. The oscillator also contains two transistorized circuits which furnish a timed relay voltage and an interrupted relay voltage to the general alarm circuits. Figure 8-18 is a block diagram.

Transistor Q1401 (fig. 8-19), is connected as a Colpitts oscillator, and generates a 1000-hertz sine wave signal. This signal is coupled to the base of emitter follower Q1402. From the emitter of Q1402 the signal is coupled through GAIN control potentiometer R1407 to the base of


+26.5V DC RELAY POWER INPUT
1-2/3 Hz FROM Q1507
VISUAL ALARM TIMER Q1406
INTERRUPTED RELAY K1402
INTERRUPTED POWER (+26.5V DC) TO RELAY K563
-22V DC
1000 HERTZ OSCILLATOR Q1401
EMITTER FOLLOWER Q1402
EMITTER FOLLOWER Q1403
1000 Hz OUTPUT
+26.5V DC RELAY POWER INPUT
TIMER Q1404
TIMED RELAY CONTROL Q1405
TIMED RELAY K1401
TIMED POWER (+26.5V DC) ALARM RELAYS
-22V DC
-22V DC

140.42

Figure 8-18.—Audiofrequency oscillator 0-721/SIA (chemical alarm), block diagram.


L1401
HVC4
1000 ~ FREQ ADJ
1000 ~ OSC
Q1401
2N43A
C1401 2.2
R1401 680
R1402 24K
R1403 1100
C1403 .25 150V
C1404 1.5 25V
C1402 2.2
CR1401 1N754A
R1404 2700
R1405 10K
C1405 2.2
R1406 10K
Q1402 2N43A
R1407 5K 1W
GAIN
C1406 2.2
R1408 680
R1409 12K
R1410 10K
Q1403 2N43A
R1411 220
C1407 2.2
C1408 22
CR1402 1N270
R1412 820
C1409 2.2
J1401
30V NEG
GND
1000 Hz OUTPUT
RELAY POWER INPUT
R1413 180
CR1403 1N270
22V
30V NEG
1 2/3 Hz INPUT
TIMED RELAY POWER OUTPUT
INTERRUPTED RELAY POWER OUTPUT
Q1404 2N492
B1
B2
C1410 47
C1411 47
R1414 100K
GENERAL ALARM TIMER ADJ.
R1415 250K 10%
R1416 330
K1401
K1402
Q1405 2N43A
CR1404 1N270
R1417 220
R1418 2700
R1419 1500
Q1406 2N43A
CR1405 1N270
R1420 620
R1421 180
R1422 10K

140.43

Figure 8-19.—AF oscillator 0-721/SIA, schematic diagram.

amplifier Q1403. The signal output is at pin 3 of connector J1401.

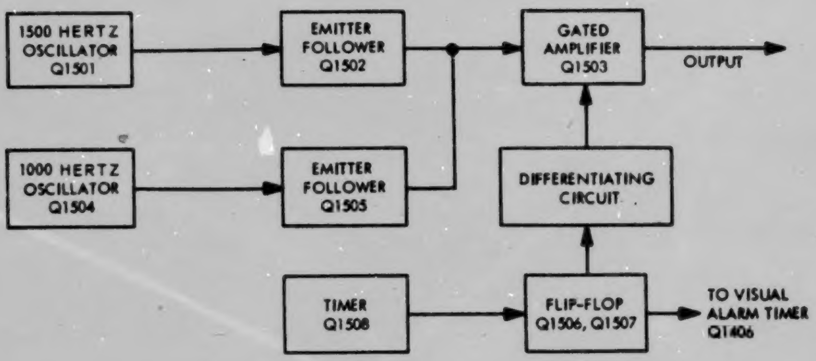
The circuits associated with the general alarm are discussed along with the general alarm oscillator discussion.

AF Oscillator 0-722/SIA

General alarm oscillator 0-722/SIA contains oscillator and timer circuits (fig. 8-20) which in conjunction with circuits in the chemical alarm oscillator, produce a simulated single-stroke, gong tone striking at the rate of 90 strokes per minute. The signal continues automatically for 15 seconds after power is applied to the circuit.

Transistors Q1501 and Q1504 (fig. 8-21) are connected as Colpitts oscillators, and generate sine wave signals at 1500 and 1000 hertz. The 1500 hertz signal from Q1501 is coupled to emitter follower Q1502, and the 1000 hertz signal from Q1504 is coupled to emitter follower Q1505. The outputs of Q1502 and Q1505 are mixed at the base of amplifier Q1503, whose emitter is gated by the timing circuit.

Unijunction transistor Q1508 is used as a timer to control flip-flop transistors Q1506 and Q1507. Potentiometer R1534 controls the timing of Q1508. The output of the flip-flop is a 1 2/3



140.44

Figure 8-20.—Audiofrequency oscillator 0-722/SIA (general alarm), block diagram.

hertz square wave having a peak-to-peak amplitude of approximately 14 volts. This square wave is differentiated by R1516 and C1510, and gates the emitter of Q1503. The output, regulated by R1512, is at pin 3 of connector J1501.

When the general alarm is actuated, -30 volts d-c is applied to pin 6 of J1401 (fig. 8-19) capacitors C1410 and C1411 begin to charge. Potentiometer R1415, resistor R1414, and capacitors C1410 and C1411 are used as an RC time constant network. Potentiometer R1415 is set so that 15 seconds after the general alarm is actuated, timer Q1404 sends out a positive pulse that cuts off Q1405. When Q1405 is cut off, relay K1401 is deenergized which disconnects the relay power input circuit from the timed relay power output, deenergizing the general alarm relays.

The 1 2/3 Hz signal output of Q1507 (fig. 8-21) is applied through pin 7 of J1401 (fig. 8-10), to the base of Q1406. This pulse turns Q1406 on and off, energizing and deenergizing relay K1402. Thus interrupted relay power is supplied through pins 9 of J1401 and J1501 to operate control relay K563 and visual alarm relay K580 (not shown).

AF Oscillators 0-724/SIA and 0-725/SIA

Unassigned alarm "A" oscillator 0-724/SIA contains transistorized oscillator and timer circuits (fig. 8-22) which generates 500 hertz and 1500 hertz sine waves alternating at the rate of 1 1/2 Hz (jump tone).

Unassigned alarm "B" oscillator 0-725/SIA generates a jump tone of 600 and 1500 Hz sine waves alternating at the rate of 6 Hz.

POWER RACK

The power rack is a deck-mounted enclosure containing two identical 500-watt power amplifiers (AF amplifier AM-2128/SIA), and a ventilation blower. Each amplifier consists of two units: the power amplifier, chassis 1; and the power supply, chassis 2 (fig. 8-23).

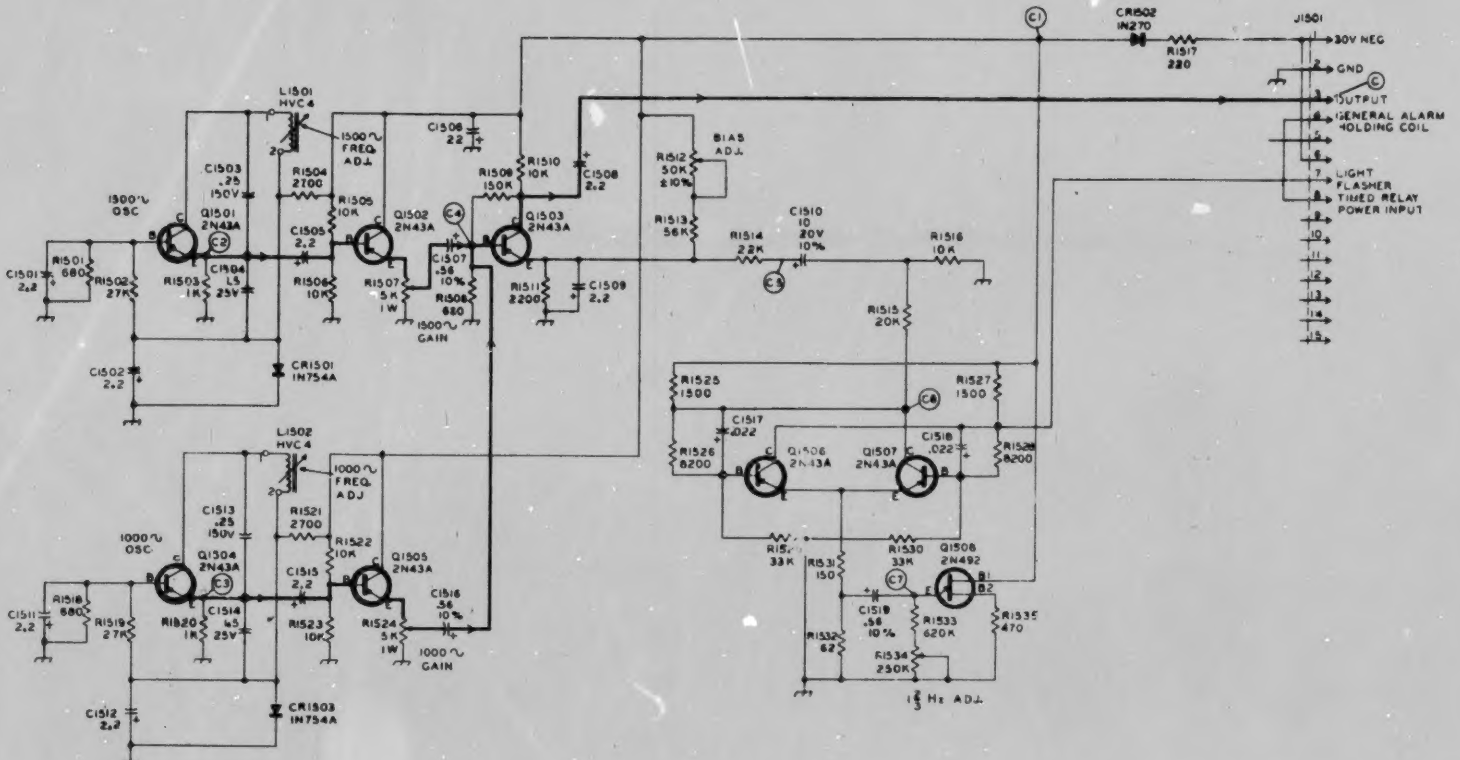
The power amplifiers, similar to the power amplifiers in the 1MC-6MC system discussed previously, consist of a voltage amplifier stage, a phase inverter stage, two driver stages, and a final amplifier stage.

INTERCOMMUNICATING SYSTEMS

Intercommunicating (intercom) systems provide for two-way transmission of orders and information between stations. Each intercom unit contains its own amplifier.

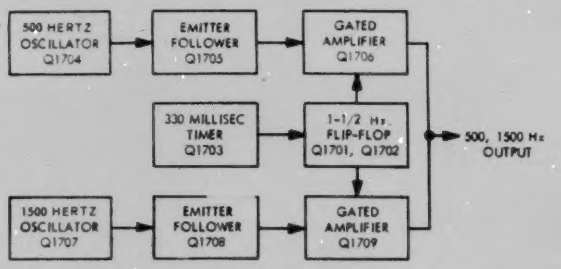
INTERCOMMUNICATING UNITS (LS-433A/SIC and LS-434A/SIC)

Regardless of their mechanical construction, intercommunicating units installed in naval vessels are to be connected together electrically in a system. The electrical characteristics that must be identical to permit interconnection in a system are the (1) audio amplifier input and output power requirements; (2) amplifier output impedance to the loudspeaker line transformer; (3) supply voltages and currents; (4) call the busy signal voltages; and (5) interconnection circuits.


J1501
1 30V NEG
2 GND
3 OUTPUT
4 GENERAL ALARM HOLDING COIL
5
6
7 LIGHT FLASHER
8 TIMED RELAY POWER INPUT
9
10
11
12
13
14
15
CR1502 1N270
R1517 220
C1
C4
C5
C6
C7
C2
C3
1500∿ OSC
Q1501 2N43A
L1501 HVC4
1500∿ FREQ. ADJ.
C1503 .25 150V
R1504 2700
R1505 10K
Q1502 2N43A
C1505 2.2
R1506 10K
R1507 5K 1W
1500∿ GAIN
C1507 .56 10%
R1508 680
C1506 22
R1509 150K
R1510 10K
C1508 2.2
Q1503 2N43A
R1511 2200
C1509 2.2
C1501 2.2
R1501 680
R1502 27K
R1503 1K
C1504 15 25V
C1502 2.2
CR1501 1N754A
BIAS ADJ.
R1512 50K ±10%
R1513 56K
R1514 22K
C1510 10 20V 10%
R1516 10K
R1515 20K
R1525 1500
R1526 8200
C1517 .022
Q1506 2N43A
Q1507 2N43A
C1518 .022
R1527 1500
R1528 8200
R1529 33K
R1530 33K
R1531 150
R1532 62
C1519 .56 10%
R1533 620K
R1534 250K
1⅔ Hz ADJ.
Q1508 2N492
B1
B2
R1535 470
1000∿ OSC
Q1504 2N43A
L1502 HVC4
1000∿ FREQ. ADJ
C1513 .25 150V
R1521 2700
R1522 10K
Q1505 2N43A
C1515 2.2
R1523 10K
R1524 5K 1W
C1516 .56 10%
1000∿ GAIN
C1511 2.2
R1518 680
R1519 27K
R1520 1K
C1514 45 25V
C1512 2.2
CR1503 1N754A

140.45

Figure 8-21.—AF oscillator 0-722/SIA, schematic diagram.



140.46
Figure 8-22.—Audiofrequency oscillator 0-724/SIA (unassigned alarm "A"), block diagram.

One type of intercom unit, the LS-433A/SIC (fig. 8-24), can originate calls up to a maximum of 10 other stations; another, the LS-434A/SIC, can originate calls up to a maximum of 20 other stations. There is no operational difference between these units. The schematic diagram of a typical intercommunicating unit is illustrated in figure 8-25.

The ship's power for the intercommunicating system is controlled by a master switch on the IC switchboard and is supplied through a TSGA cable. The TSGA cable interconnects the units in parallel for the single-phase 115-volt power supply and the signal circuit common line. The 115-volt power is fused at each unit. The audio and signal lines (excluding the signal circuit common) of the units in the system are interconnected with a TTHFWA cable.

The intercommunicating unit is housed in a steel cabinet designed for bulkhead mounting. It will withstand shock, vibration, and salt spray, and will perform under extremes of temperature and high humidity. The components consist essentially of a reproducer, controls, and amplifier.

Reproducer

The reproducer serves as a microphone to transmit sound from the unit to other units in the system and as a loudspeaker to reproduce sound transmitted to the unit by any other unit. An incoming call can be heard through the loudspeaker because amplification is accomplished by the amplifier of the calling unit.

Controls

The controls consist of the talk switch, handset and microphone talk, pushbutton assembly, busy light, call light, volume cntrol, and dimmer control.

The TALK SWITCH, S26 (fig. 8-25), serves to select the function of the reproducer. When the switch is depressed, the reproducer functions as a microphone and the output of the amplifier of the calling station is electrically connected to the reproducer of the called station. When the switch is released the reproducer functions as a loudspeaker. The talk switch is spring loaded and returns to the listen or standby position when released.

A HANDSET can be used with the intercommunicating unit in place of the reproducer. The operation is the same as that of the reproducer except that the pushbutton in the handset is used as a talk switch in place of the regular talk switch on the front panel. Incoming calls will be heard simultaneously in the handset and in the reproducer. The volume control will control the level of the incoming call to the reproducer only.

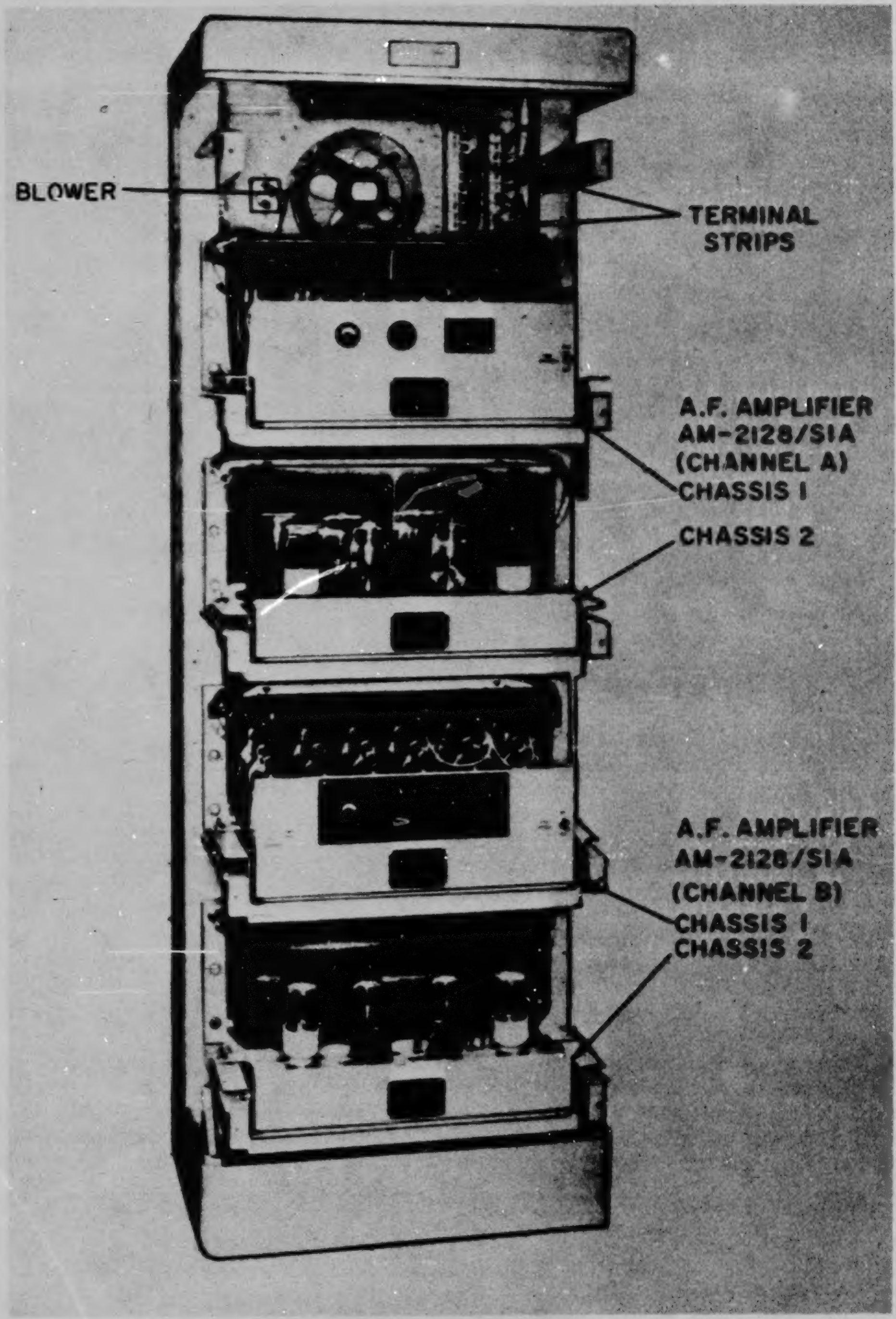
A PORTABLE MICROPHONE can also be used with the equipment. The operation is the same as that of the reproducer, except that the pushbutton on the microphone is used as a talk switch instead of the regular talk switch on the equipment.

The PUSHBUTTON ASSEMBLY, or station selector buttons, are located at the top of the front panel. The locations or designations of the various units in the system are engraved in the station designation plate below the associated selector buttons. When the station selector buttons are depressed they will lock in the operated position until the release pushbutton is depressed to return them to the nonoperated position.

The 10-station unit is provided with one bank of station selector switches, whereas the 20-station unit is provided with two banks of selector switches. In the 20-station unit, however, the latchbar switches and release pushbuttons are electrically interconnected.

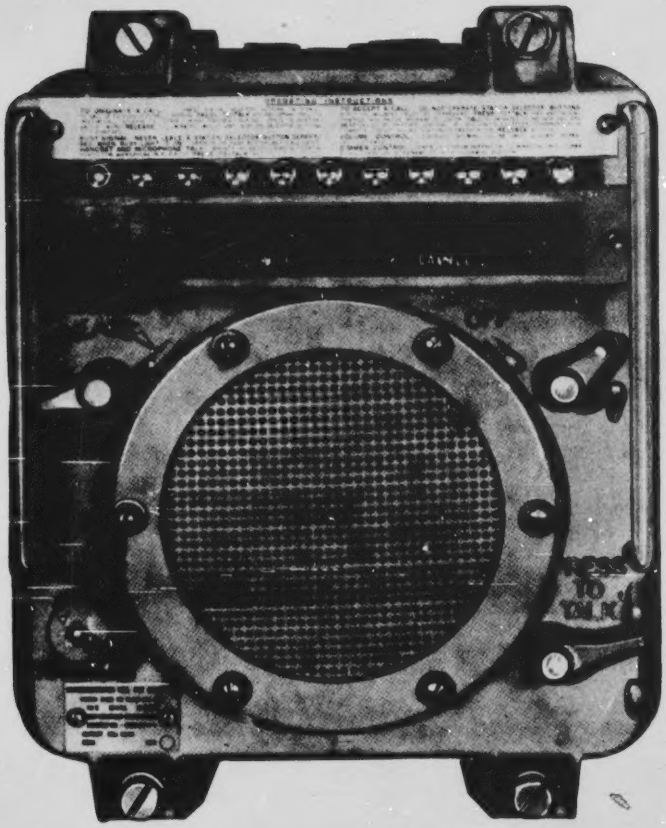
One bank of selector switches consist of the switch mechanism, 11 pairs of spring pile-up switches, and a latch bar switch. Each pair of pile-up switches (consisting of an upper pile-up designated S1U, S2U, and so forth, and a lower pile-up designated S1L, and so forth, is operated simultaneously by a separate release pushbutton.

During standby periods the release pushbutton is kept in the depressed, or operated position. When any station selector button is depressed, the release pushbutton will automatically return to the nonoperated position and the release lamp under the pushbutton will be


BLOWER
TERMINAL STRIPS
A.F. AMPLIFIER AM-2128/SIA (CHANNEL A)
CHASSIS 1
CHASSIS 2
A.F. AMPLIFIER AM-2128/SIA (CHANNEL B)
CHASSIS 1
CHASSIS 2

140.47

Figure 8-23.—Amplifier assembly AM-2316/SIA (power rack).



7.25(74)

Figure 8-24.—Intercommunicating unit (LS-433A/SIC).

lighted. At the conclusion of a conversation the release pushbutton must be depressed to extinguish the release lamp and return any station selector buttons which were operated, to the nonoperated position.

The BUSY lamp is lighted when a station button is depressed to call another station and the station being called is busy. Do not leave a station selector button depressed when the busy lamp is lighted. Depress the release pushbutton and call later.

The DIMMER CONTROL, S27, (fig. 8-25) controls all illumination of the unit. The signal lights are off when the control knob is in the extreme counterclockwise position and are fully lighted for all other positions as the knob is turned clockwise. The station designation lights are lighted for all positions of the control knob and the illumination increases as the knob is turned clockwise.

The VOLUME CONTROL, S25, is associated with a variable impedance output transformer, T2, inside the unit. As the knob is rotated, the electrical energy passing through the transformer to the loudspeaker is increased and the volume of sound output of the loudspeaker is correspondingly increased. This control has no effect on the volume of the outgoing sound from the unit. Thus, each unit in the system can control the incoming volume to the desired level.

Amplifier

The amplifier is a 3-stage push-pull amplifier consisting of the input transformer, T1,

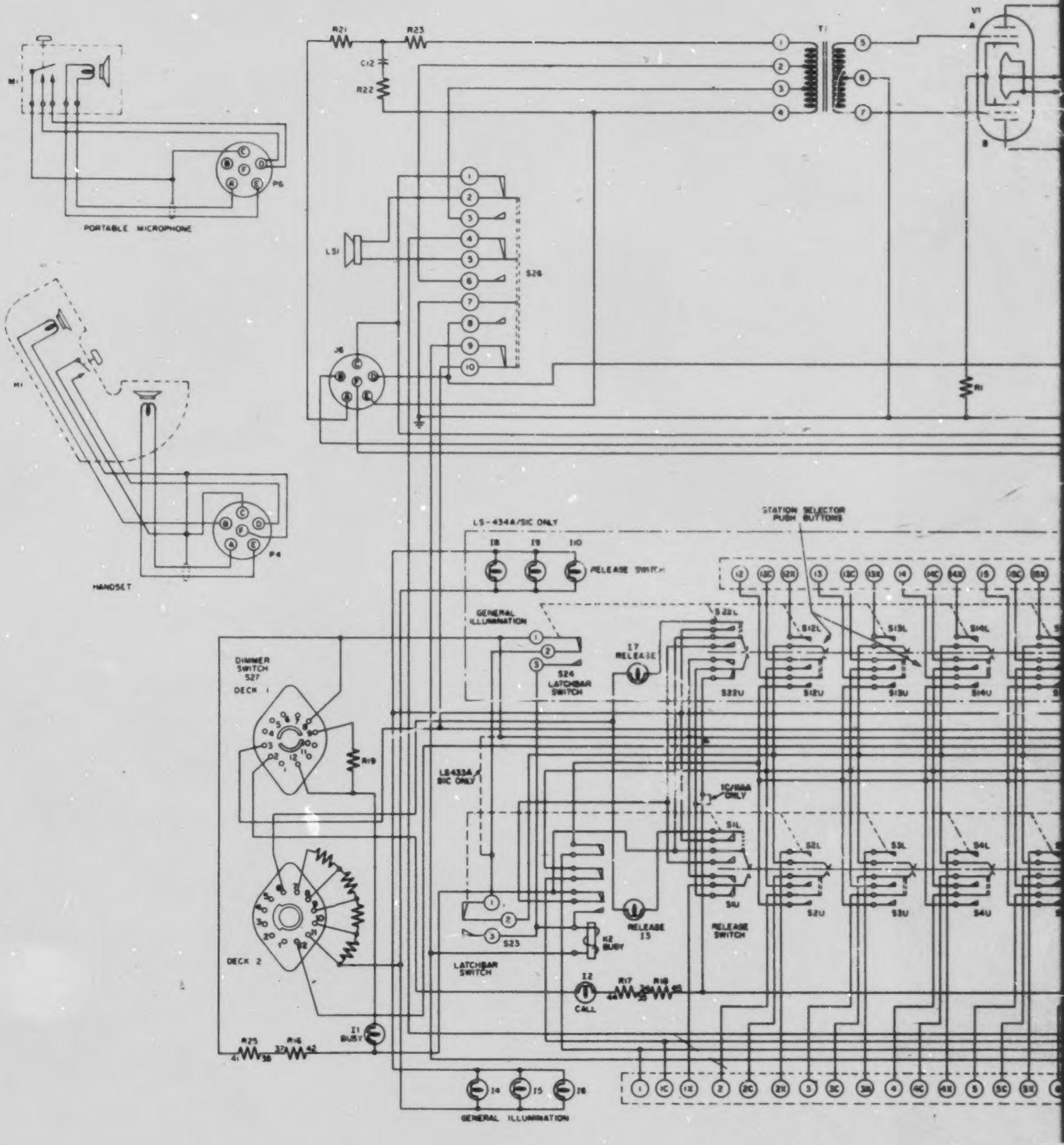
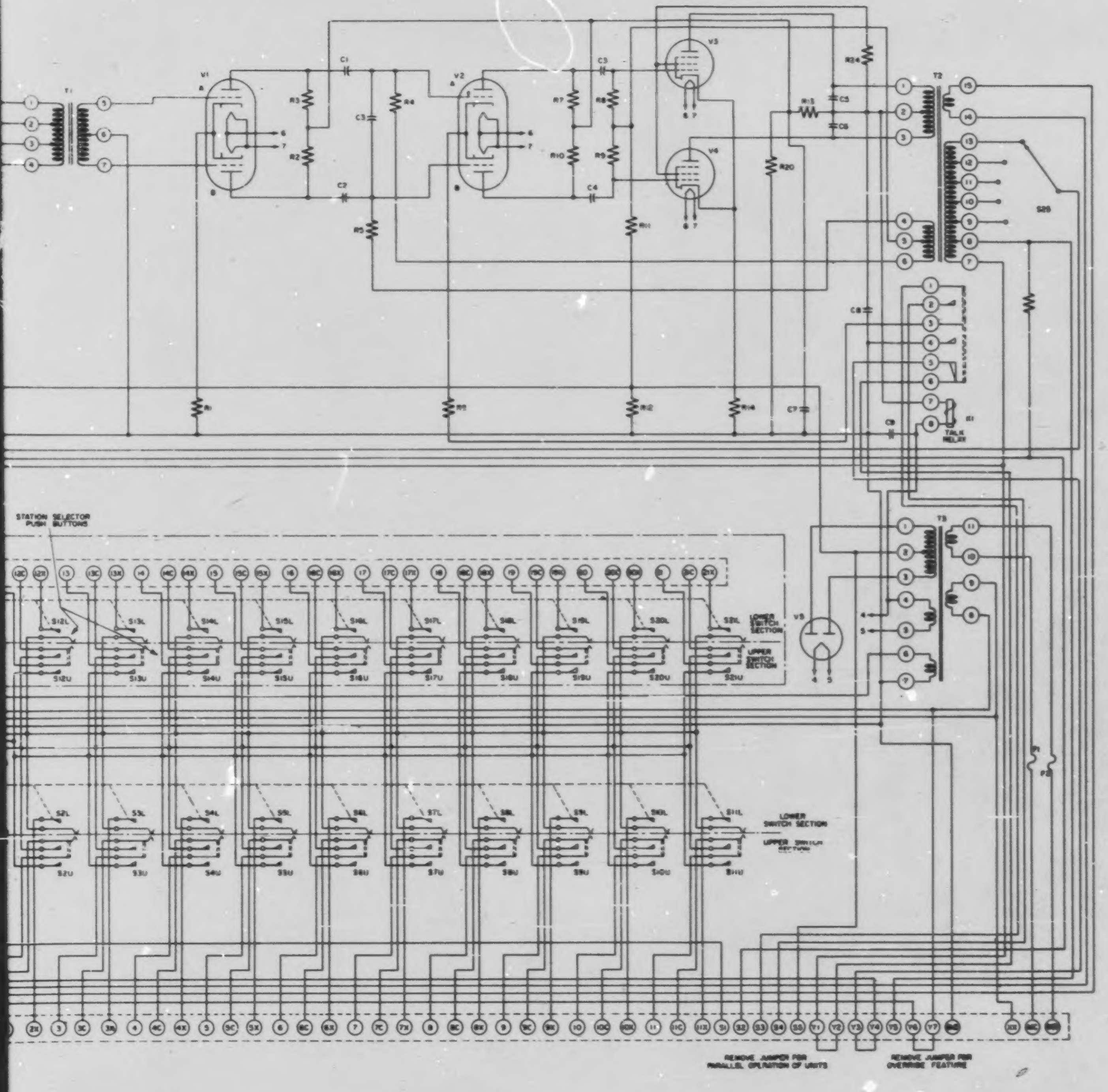

R21
R23
C12
R22
T1
V1
A
B
M1
P6
PORTABLE MICROPHONE
LS1
S26
J6
H1
P4
HANDSET
R1
STATION SELECTOR PUSH BUTTONS
LS-434A/SIC ONLY
I8
I9
I10
RELEASE SWITCH
12
12C
12X
13
13C
13X
14
14C
14X
15
15C
15X
GENERAL ILLUMINATION
S22L
S12L
S13L
S14L
S24 LATCHBAR SWITCH
I7 RELEASE
S22U
S12U
S13U
S14U
DIMMER SWITCH S27
DECK 1
R19
LS433A/SIC ONLY
IC/10AA ONLY
S1L
S2L
S3L
S4L
S1U
S2U
S3U
S4U
RELEASE I3
K2 BUSY
S23
LATCHBAR SWITCH
RELEASE SWITCH
DECK 2
I2 CALL
R17
R18
R25
R16
I1 BUSY
I4
I5
I6
GENERAL ILLUMINATION
1
1C
1X
2
2C
2X
3
3C
3X
4
4C
4X
5
5C
5X

Figure 8-25.—Schematic diagram of i


T1
V1
V2
V3
V4
V5
C1
C2
C3
C4
C5
C6
C7
C8
C9
R1
R2
R3
R4
R5
R7
R8
R9
R10
R11
R12
R13
R14
R15
R20
R24
T2
T3
S26
TALK RELAY
K1
F1
STATION SELECTOR PUSH BUTTONS
LOWER SWITCH SECTION
UPPER SWITCH SECTION
S2L
S3L
S4L
S5L
S6L
S7L
S8L
S9L
S10L
S11L
S12L
S13L
S14L
S15L
S16L
S17L
S18L
S19L
S20L
S21L
S2U
S3U
S4U
S5U
S6U
S7U
S8U
S9U
S10U
S11U
S12U
S13U
S14U
S15U
S16U
S17U
S18U
S19U
S20U
S21U
S1
S2
S3
S4
S5
Y1
Y2
Y3
Y4
Y5
Y6
Y7
REMOVE JUMPER FOR PARALLEL OPERATION OF UNITS
REMOVE JUMPER FOR OVERRIDE FEATURE

7.26

-25.—Schematic diagram of intercommunication unit.

double triodes, V1 and V2, beampower tubes, V3 and V4, output transformer, T2, and the power supply rectifier twin diode, V5.

The primary of T1 is tapped to match it either to the internal loudspeaker, LS1, used as a microphone, or to an external microphone over a frequency compensating network consisting of R21, R22, R23, and C12. The secondary of T1 drives the grids of the first voltage amplifier stage, V1.

Resistance-capacitance coupling is used between the three stages of the amplifier. The output of the power stage, V3 and V4, is coupled through the output transformer, T2, to the voice transmission line. When the amplifier is not in use (when receiving calls), transformer, T2, acts as a line transformer. Calls are received over the voice transmission line and are coupled over a separate winding to the loudspeaker, LS1. This winding is provided with taps connected to the switch-type volume control, S25, to change the step-down voltage ratio of T2 and thus control the volume of the incoming signal.

During the standby periods the plate current of V2 is cut off completely and the plate current of the output tubes, V3 and V4, is reduced to a very low value. This reduction in plate current is accomplished by the voltage drop across R12 connected between the center tap of the high-voltage winding of T3 and ground. This voltage increases the bias on V3 and V4. The d-c voltage on the filter capacitors C7, C8, and C9 is substantially the same during standby periods (no load) and during periods of speech (load) because R12 changes the rectifier circuit from capacitor-input (with load) to resistor-input on no load. The reduced voltage with capacitor input on load is approximately the same as with resistor input on no load. Resistor, R12, is in series with C9 during standby periods.

This type of cutoff circuit eliminates voltage surges on the capacitors when switching from standby to ready conditions and also eliminates the delay caused by charging of the capacitors. To ready the amplifier for outgoing speech, R12 is shorted by operating the loudspeaker, LS1, talk switch, S26, (terminals 7 and 8); by pressing the pushbutton in the auxiliary handset or microphone (terminals C and D on J6); or by operating an external switch connected to terminals S5 and GND.

The upper end of resistor, R11, is connected from the junction of R8 and R9 to ground (R12 being shorted during ready periods.) Any unbalance in the audio voltages reaching the grids of V3 and V4 will develop a voltage across R11. The upper end of resistor, R11, is also connected to terminal 5 of the feedback winding on T2. Terminal 6 of this winding is connected to the V2A grid via R4 and terminal 4 is connected to the V2B grid via R5. The unbalanced voltage developed across R11 will be fed back to the grids of V2A and V2B through R4 and R5 respectively in the proper phase to correct the unbalanced condition. The cathode circuit of V2A and V2B is returned to ground through contacts 3-4 of the talk relay, K1.

Negative feedback is incorporated in the design of the amplifier to lower the apparent output impedance and to develop a 70-volt output (within 3 db) when the amplifier is delivering 10 watts to any combination of from one to four other intercommunicating units. The feedback is developed by the separate winding on the combination output-line transformer, T2 (terminals 4, 5, and 6). The voltage is fed back symmetrically to the grids of V2 through R4 and R5.

OPERATION

To call a particular station, depress the station selector switch of the desired station (S2 through S11), depress the talk switch, S26, and speak directly into the grille. Release the talk switch, S26, to listen. When the conversation is completed, depress the release pushbutton, S1, to return the selector pushbutton to the nonoperated position.

To accept a call from another station, listen to the incoming call through the loudspeaker. Do not operate any of the station selector pushbutton switches. Depress the talk switch, S26, to reply to the incoming call. The call light is illuminated to indicate the station is being called by another station. If the call light remains illuminated after the conversation is completed, remind the calling station to depress his release pushbutton.

The audio circuit between two stations is illustrated by the simplified schematic diagram in figure 8-26. The talk switches at both stations are shown in the normal (listen) position. When the talk switch, S26, at either station is depressed, the voice coil leads of the loudspeaker are shifted from terminals 7 and 13 of the secondary of T2 to the input transformer, T1, of the associated amplifier. At the same time contacts 7-8 of S26 (fig. 8-25) are closed to short resistor, R12, to ground, thereby decreasing the bias on V3 and V4. This action increases

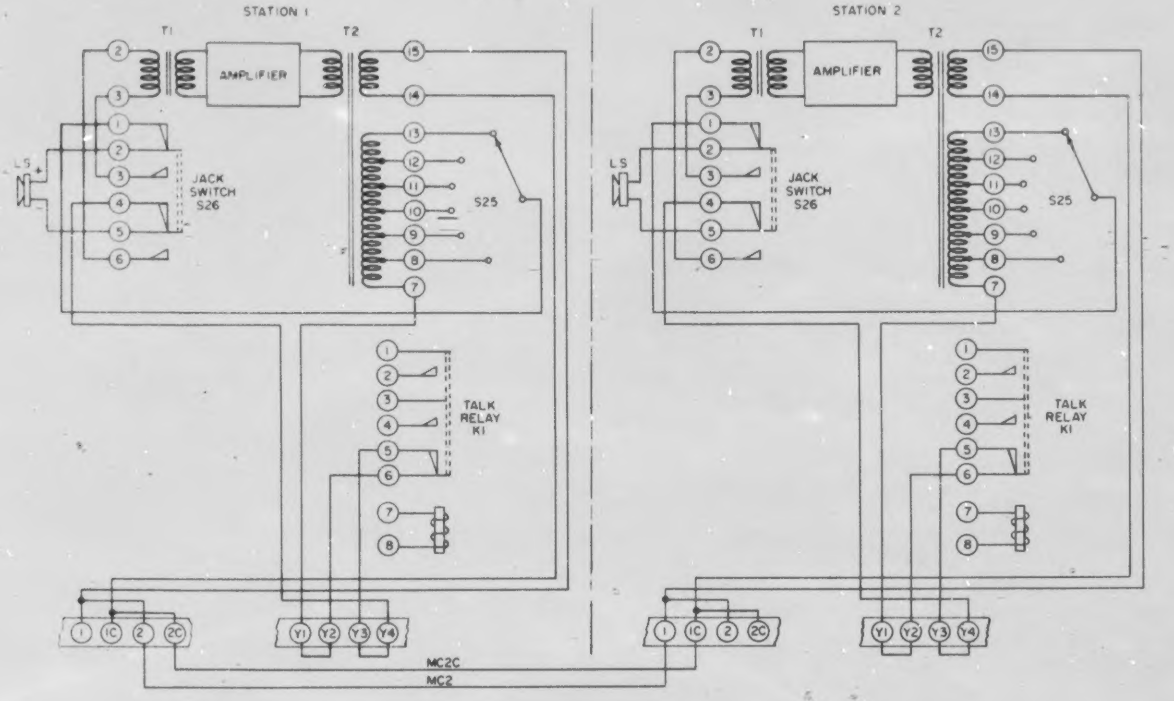


Figure 8-26.—Schematic diagram of audio lines between two stations. 7.27

the V3 and V4 plate current through the operating coil terminals 7-8 of relay, K1. The increase in plate current operates relay, K1, to close contacts 3-4 and completes the circuit from the V2 cathodes through R6 to ground. This action applies plate voltage to V2 and the amplifier at the talking station is placed in the ready condition.

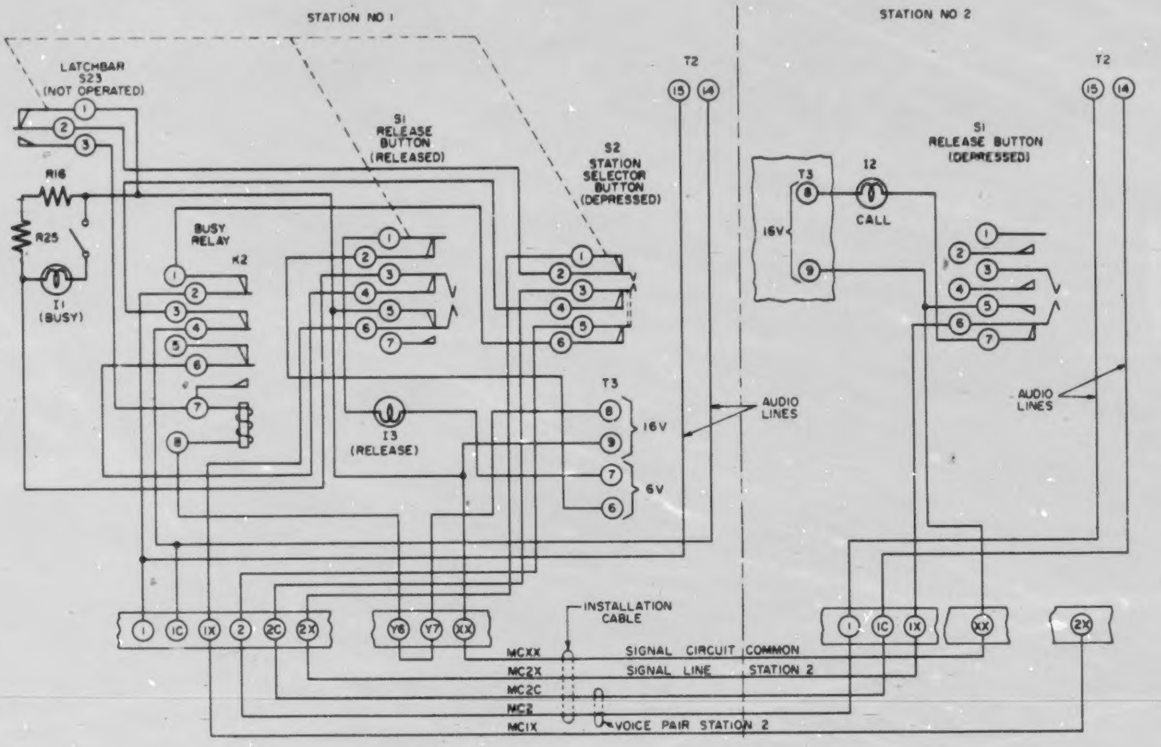
The voice signals are amplified and applied to terminals 14 and 15 of T2 at the listening station and appear across terminal 7 of T2 and the moving contact of the volume control, S25, and then to the loudspeaker.

The amplifier of the listening station is in a standby condition. In the standby condition the plate current of V2 (fig. 8-25) is completely cut off, and that of V3 and V4 is reduced to a very low value by the voltage drop across R12, which is in the negative high-voltage center tap 2 of T3 to ground.

Station 1 Calling Idle Station 2

The signaling circuits between two stations are illustrated by the simplified schematic diagram in figure 8-27. Terminal 9 of the 16-volt winding of the power transformer, T3, in both stations is connected through terminal XX to the signal circuit common MCXX, which is connected in parallel with all XX terminals throughout the system. Terminal 8 of T3 at station 1 is connected to terminal 8 of the busy relay, K2. When the station selector pushbutton switch S2, is depressed to call (idle) station 2, the release pushbutton, S1, will be released as soon as S2 is depressed. The latchbar switch, S23, will operate to momentarily connect terminal 7 of the busy relay, K2, to the signal line, MC2X. The circuit is from terminal 7 of busy relay K2, contacts 3-2 of S23, contacts 2-1 of S2, to terminal 2X, and to line MC2X. If station 2 is idle, line MC2X will be connected to terminal 8 of T3 at station 2. The circuit is from line MC2X to terminal 1X of station 2, contacts 6-7 of S1, through call lamp I2, and to terminal 8 of T3.

During the time that latchbar switch, S23, is momentarily operated, terminal 7 of busy relay, K2, at station 1 is connected to terminal 8 of T3 at station 2 through call lamp I2. Terminal 8 of K2 at station 1 is connected to terminal 8 of T3


STATION NO 1
STATION NO 2
LATCHBAR
S23
(NOT OPERATED)
R16
R25
I1
(BUSY)
BUSY
RELAY
K2
S1
RELEASE
BUTTON
(RELEASED)
S2
STATION
SELECTOR
BUTTON
(DEPRESSED)
T2
15
14
I3
(RELEASE)
T3
16V
6V
AUDIO
LINES
I2
CALL
S1
RELEASE BUTTON
(DEPRESSED)
INSTALLATION
CABLE
1
1C
1X
2
2C
2X
Y6
Y7
XX
MCXX
MC2X
MC2C
MC2
MC1X
SIGNAL CIRCUIT COMMON
SIGNAL LINE STATION 2
VOICE PAIR STATION 2

7.28

Figure 8-27.—Schematic diagram of signaling circuits between two stations.

at the same station. Terminal 8 of T3 at station 1 is at the same potential as terminal 8 of T3 at station 2 and K2 does not operate.

As soon as latchbar, S23, releases terminal 7 of busy relay, K2, is open-circuited and the connections of both the audio (heavy) lines and the signal (light) lines between the two stations are established. The call lamp, I2, is lighted at station 2. The signal circuit is from terminal 8 of T3 to I2, contacts 7-6 of S1, to terminal IX, over signal line MC2X to terminal 2X of station 1, contacts 1-2 of S2, contacts 2-1 of S23, to terminal XX, over signal common line MCXX, to terminal XX of station 2, and to terminal 9 of T3.

The release lamp, I3, at station 1 is lighted (S1 released when S2 was depressed). The circuit is from terminal 7 of T3 at station 1, to release lamp I3, contacts 1-2 of S1, and to terminal 6 of T3. Line MCIX is connected to line MCXX. The circuit is over line MC1X to terminal 1X of station 1, contacts 6-5 of S1, to terminal XX of station 1, and to signal line common MCXX. Line MC2X is also conntected to line MCXX. The circuit is from terminal 2X of station 1, contacts 1-2 of S3, contacts 2-1 of S23, to terminal XX of station 1, and to line MCXX.

Station 1 Calling Busy Station 2

When the station selector pushbutton switch, S2, is depressed at station 1 to call station 2, which is busy (line MC2X connected to line MCXX by another parallel connected station not shown), the release pushbutton, S1, will be released as soon as S2 is depressed. The latchbar switch, S23, will momentarily operate to energize the busy relay, K2. The circuit is from terminal 8 of T3, terminals Y7-Y6 of station 1, terminals 8-7 of busy relay K2, contacts 3-2 of S23, contacts 2-1 of S2, to terminal 2X, over

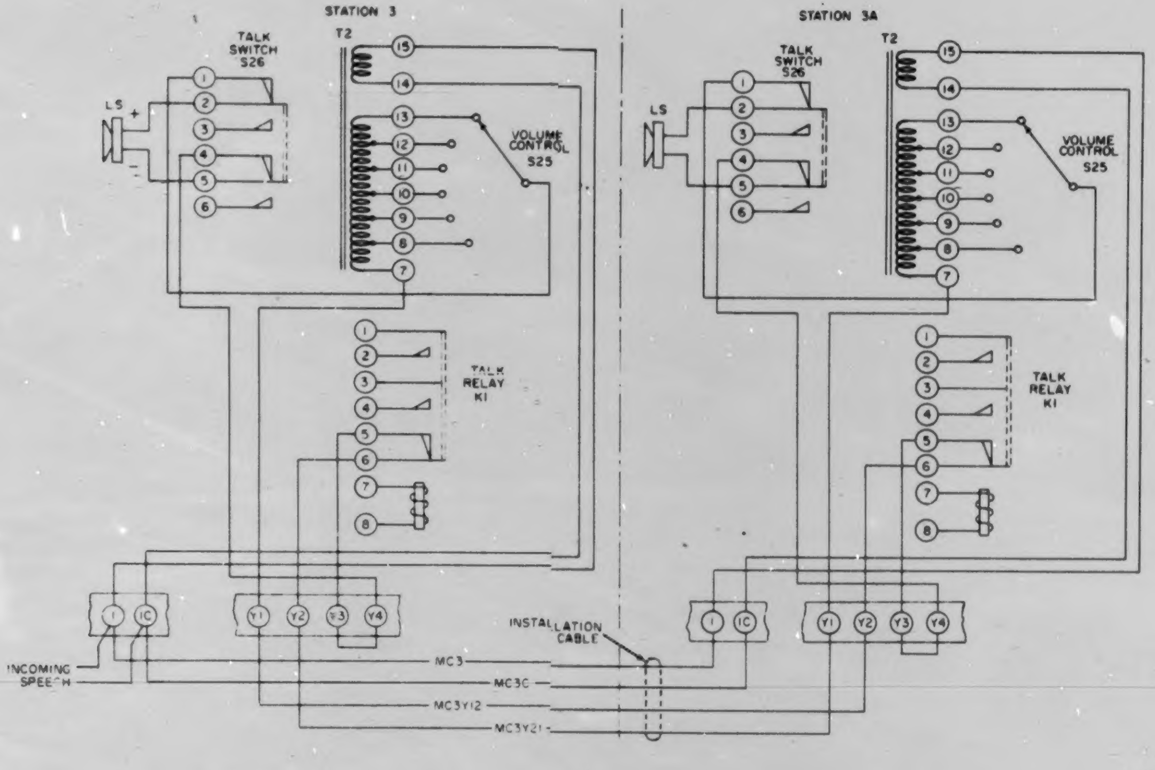

STATION 3
TALK SWITCH S26
T2
LS
+
-
VOLUME CONTROL S25
TALK RELAY K1
STATION 3A
TALK SWITCH S26
T2
LS
VOLUME CONTROL S25
TALK RELAY K1
1
1C
Y1
Y2
Y3
Y4
INSTALLATION CABLE
INCOMING SPEECH
MC3
MC3C
MC3Y12
MC3Y21
7.29

Figure 8-28.—Schematic diagram of two stations in parallel.

signal line MC2X to terminal 1X of station 2, contacts 6-5 of S1 (released), terminal XX of station 2, over signal common MCXX, terminal XX of station 1, and to terminal 9 of T3.

The busy relay, K2, will lock in the operated position after latchbar switch, S23, opens. The circuit is from terminal 8 of T3, terminals Y7-Y6, terminal 8 and contacts 7-6 of busy relay K2, contacts 4-3 of S1, to the busy lamp I1, and to terminal 9 of T3. The busy lamp, I1, is now in series with the coil of busy relay, K2, and will be lighted. The audio lines from terminals 14 and 15 of T2 to line MC2 and line MC2C will be open at contacts 3-4 and 1-2, respectively, of busy relay, K2, which is operated.

The normal connection of the audio line from terminal 14 of T2 (station 1) is through contacts 4-3 of busy relay, K2 (released), contacts 4-3 of S2 (depressed), to terminal 2C, and to line MC2C. The normal connection of the audio line from terminal 15 of T2 is through contacts 2-1 of busy relay, K2 (released), contacts 6-5 of S2 (depressed), to terminal 2, and to line MC2.

Parallel Operation of Two Adjacent Stations

The operation of two intercom stations in parallel is illustrated by the simplified schematic diagram in figure 8-28. The incoming speech from a remote station will be heard at both stations 3 and 3A, and replies can be made from either station. Either station can call a third station but both stations cannot call at the same tume. When the talk switch, S26, at station 3 is depressed to transmit a message, the talk relay, K1, at station 3A is operated to open the circuit to the loudspeaker and prevent acoustic feedback (not shown).

The incoming speech lines, 1 and 1C, of station3 are connected to terminal 15 and 14 respectively on transformer, T2.

The 14-15 winding of T2 at both stations couples the incoming speech to the tapped windings of T2 which include the volume controls, S25. Thus the incoming signals appear across terminals 7 of T2 and the moving contact of the volume control, S25, at both stations. These signal sources are connected in series addition through a closed loop containing both loudspeakers.

The circuit is from the arm of S25 at station 3, contacts 1-2 of S26, the loudspeaker, contacts 4-5 of S26, terminals Y4 and Y3, contacts 5-6 of K1, terminal Y2 over line MC3Y21 to terminal Y1 of station 3A, terminal 7 of T2, the arm of S25, contacts 1-2 of S26, the loudspeaker, contacts 4-5 of S26, to terminals Y4-Y3, contacts 5-6 of K1, terminal Y2, over line MC3Y12, terminal Y1 in station 3, to complete the circuit at terminal 7 of T2.

The volume at both stations will be the same and can be controlled by either volume control, S25. Both volume controls, however, should be kept at the same setting.

If the talk relay, K1, is operated at either station, the input to the audio circuit will be open for both stations.

MAINTENANCE

A test fixture is provided with the maintenance parts of the equipment to facilitate testing the intercom units. The test fixture is housed in a metal case and includes the necessary switches, resistors, and controls to perform all essential tests on a unit. It is provided with a line cord and plug for connection to the ship's 115-volt 60-hertz power supply, and suitable female connectors for attaching it to the rear of the unit under test. The front cover contains 11 DPDT test switches, S201 through S211, a SPST call lamp test switch, S212, a SPST talk test switch, S213, a DPDT polarity test switch, S214, and an indicator lamp, I201 (fig. 8-29).

To use the test fixture, remove the intercom unit to be tested from its case and attach the test fixture to the rear of the unit by plugging it into the unit and connecting the line cord and plug to the ship's 115-volt 60-hertz power. On the test fixture, operate the talk switch, S213, to the OFF position and the 11 test switches, S201 through S211, to the STANDBY position. On the unit under test, depress the release pushbutton, S1, turn the volume control, S25, and dimmer control, S27, to the extreme clockwise positions, and connect a microphone or handset into the microphone jack, J6 (fig. 8-25).

Polarity Test

To test the polarity of the unit, operate the polarity test switch, S214 (fig. 8-29), to the OK WHEN LIT position (not shown). The indicator lamp, I210, should light with full intensity if the polarity is correct. Now operate the polarity test switch, S214, to the REVERSED position (not shown). The indicator lamp should go out if the polarity is not correct. The lamp may glow faintly but it is not important. The polarity test checks the polarity of the line and signal voltage windings (terminals 10-11 and 8-9 respectively) of the power transformer, T3 (fig. 8-25).

Call Lamp Test

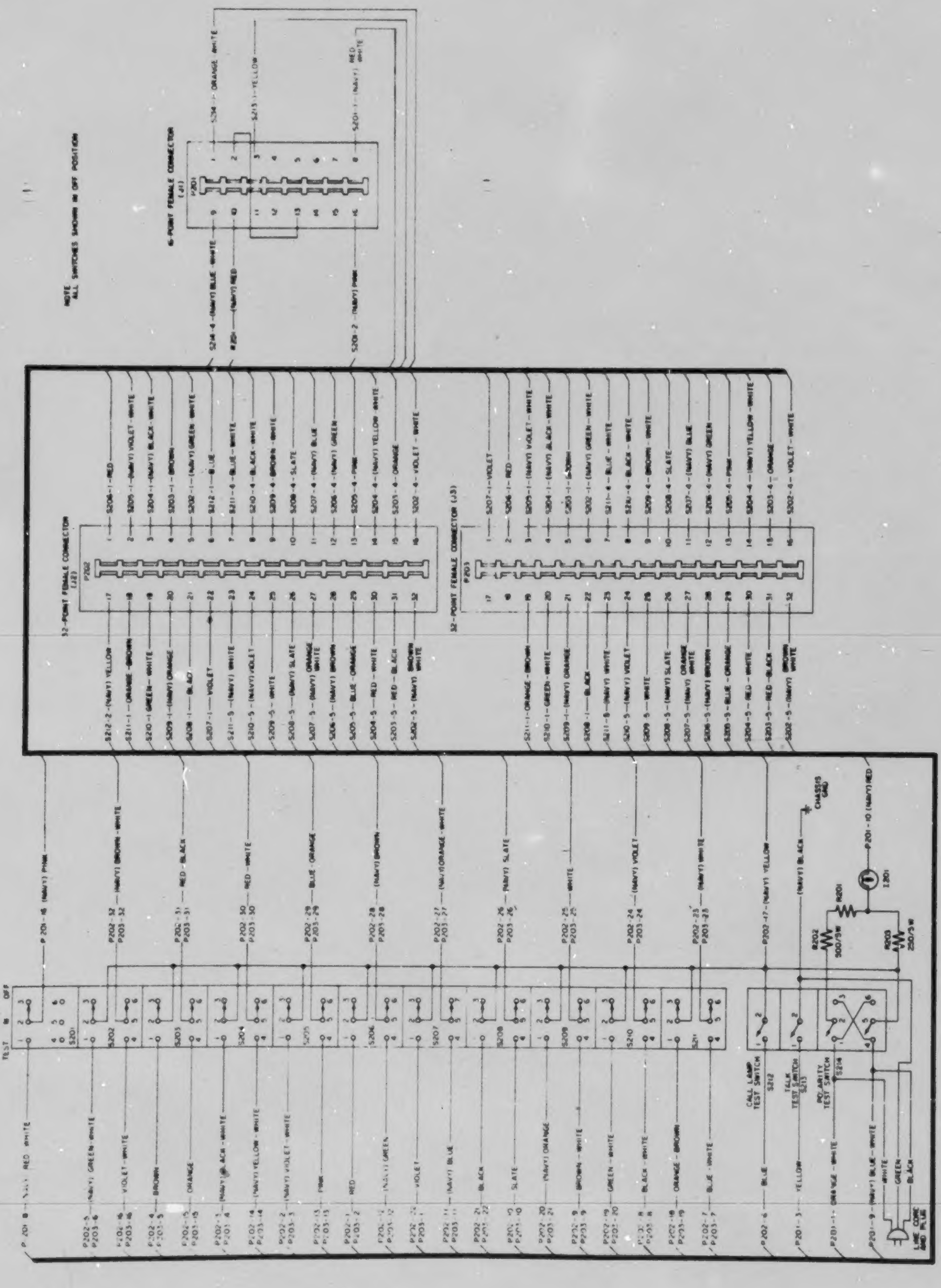
To test the call lamp of the unit, operate the call lamp test switch, S212, on the test fixture. The call lamp, I2 (fig. 8-25) on the unit under test should be lighted.

Amplifier and Reproducer Test

To test the amplifier and reproducer, depress the (microphone) talk switch and talk into the microphone. The talker should hear his voice clearly through the reproducer. Rotate the volume control knob, S25, on the unit under test while talking into the microphone, and observe the effect on the output volume. Now place the microphone close to the reproducer. A microphone feedback should be observed when the volume control is in the full-volume position as well as at one step below full volume. This test provides a rough indication of the amplifier gain, power output, and the general performance of the entire unit, except for the signaling circuits.

Station Selector Circuit Test

On the test fixture (fig. 8-29), operate the talk test switch, S213, to the TALK position with the microphone reasonably close to the reproducer to produce a microphonic howl. Reduce the volume control to the minimum position at which the howl can still be obtained by moving the microphone as close to the reproducer as required. This position will preduce the minimum objectionable howl during the subsequent station selector circuit tests.


NOTE
ALL SWITCHES SHOWN IN OFF POSITION
16-POINT FEMALE CONNECTOR (J1)
P201
32-POINT FEMALE CONNECTOR (J2)
P202
32-POINT FEMALE CONNECTOR (J3)
P203
TEST SWITCHES S201 THROUGH S211
TEST N OFF
CALL LAMP TEST SWITCH S212
TALK TEST SWITCH S213
POLARITY TEST SWITCH S214
CHASSIS GND
R201
R202 500/3W
R203 250/3W
I201
LINE CORD AND PLUG

7.30

Figure 8-29.—Wiring diagram of test fixture for LS-433A/SIC.

On the test fixture, operate the test switch, S210, to the TEST position which should stop the microphonic howl. Then restore S210 to the STANDBY position. This test checks the circuit from terminals 1 and 1C, through the busy relay, K2, (not operated) to the line winding terminals 14 and 15 of the output transformer, T2 (fig. 8-25). When test switch, S201, is in the TEST position, it places a short circuit across terminals 1 and 1C to interrupt the microphonic howl.

On the unit under test, depress the station selector pushbutton, S2 (adjacent to release pushbutton S1). On the test fixture operate the test switch, S202, to the TEST position which should interrupt the microphonic howl. Then restore S202 to the STANDBY position and depress the release pushbutton, S1, on the unit under test. This test checks the continuity between terminals 2 and 2C (fig. 8-25) through switch S2U and busy relay K2 to the line winding terminals 14 and 15 of transformer T2.

Similarly, on the unit under test, depress the remaining station selector pushbuttons S3 through S11, using the corresponding test switches, S203 through S211, on the test fixture for each test. This test checks the continuity of the various audio circuits. If the unit under test is provided with facilities for originating calls to 20 stations, repeat the foregoing tests, using the second row of station selector pushbuttons, S12 through S21.

Signal Circuit Test

On the test fixture (fig. 8-29) operate the talk test switch, S213, to the OFF position and the 11 test switches, S201 through S211, to the STANDBY position. On the unit under test, depress the release pushbutton, S1, for the subsequent signal circuit tests.

On the test fixture, operate test switch, S202, to the TEST position and on the unit under test, depress the station selector pushbutton, S2. The busy lamp, I1, should light. On the unit under test, depress the release pushbutton, S1, and again depress the station selector switch, S2. The busy lamp, I1, should go out and again light. Repeat this test several times in rapid succession. On the test fixture, restore test switch, S201, to the standby position and on the unit under test, depress the release pushbutton, S1.

When the test switch, S202, on the test fixture is operated to the TEST position, it makes station 2 busy by connecting terminal 2X to terminal XX (fig. 8-25). When the station selector pushbutton, S2, on the unit under test is depressed to select station 2, it checks the busy circuit through the lower switch assembly, S2L, busy relay, K2, latchbar switch, S23, and associated wiring. It also checks the operation of the upper switch assembly, S2U, and associated wiring.

On the test fixture, operate the test switch, S203, to the TEST position and on the unit under test, depress the station selector pushbutton, S3. The busy lamp I1 should light. Restore the test switch, S203, to the STANDBY position and depress the release pushbutton, S1. This test checks the operation of the busy relay, K2, the lower switch assembly, S3L, the latchbar switch, S23, and associated wiring. It also checks the operation of the upper switch section, S3U, and associated wiring.

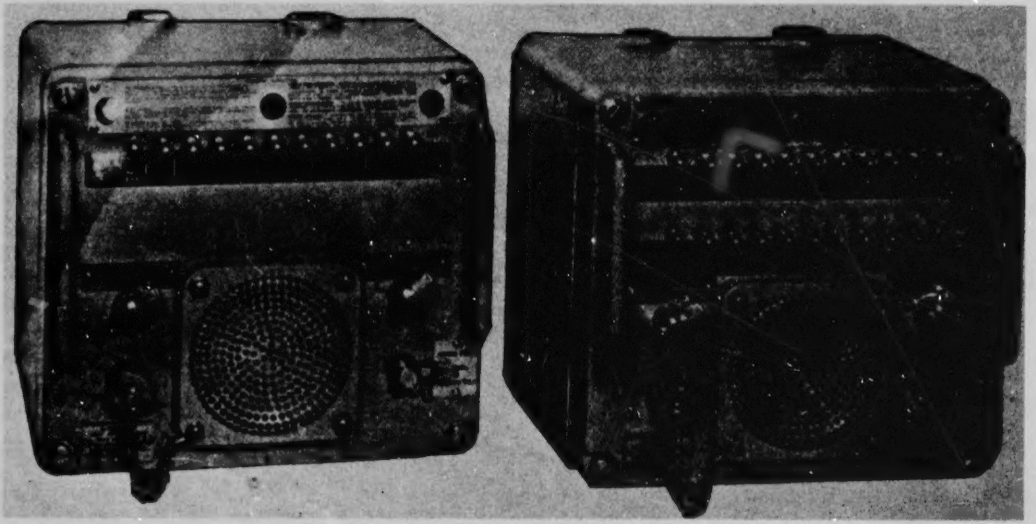
Test the remaining pushbuttons by operating first the test switches, S204 through S211, to the TEST position on the test fixture and then depressing the corresponding station selector pushbuttons S4 through S11, on the unit under test. If the unit under test is a 20-station type repeat the foregoing tests, using the second row of station selector pushbuttons, S12 through S21.

The manufacturer's technical manual furnished with the equipment installed in your ship contains more detailed information concerning the operation, repair, and maintenance of intercommunicating units.

INTERCOMMUNICATING UNITS LS-518/SIC AND LS-519/SIC

The LS-518/SIC and LS-519/SIC intercoms (fig. 8-30) are 10-station and 20-station units, respectively. Both are fully transistorized intercoms that operate in much the same way as the older 433A and 434A types. Refer to the overall functional diagram, figure 8-31. The darkened SOLID line in this figure shows that the audio from the calling loudspeaker is amplified, and transmitted via the station selector switches to the called station. The darkened BROKEN line shows that the audio from the calling station goes into the speaker of the local called station, via the output transformer T3, volume control S25, and relay contacts of K1, K4, and K3.

The main differences between the older intercoms and the fully transistorized units concern the connection of a remote loudspeaker (Model S-223) and the addition of a so-called handsfree position to the press-to-talk switch. Connecting the loudspeaker calls for some minor



140.127

Figure 8-30.—Intercommunicating units, Type LS-518/SIC & LS-519/SIC.

wiring changes, such as cutting the leads on the switch assembly. Complete instructions for connecting the loudspeaker are contained in the manufacturer's technical manual. When the press-to-talk switch is in the hands-free position, the calling station controls the transmitting or receiving function; the receiving station need not press the switch to talk.

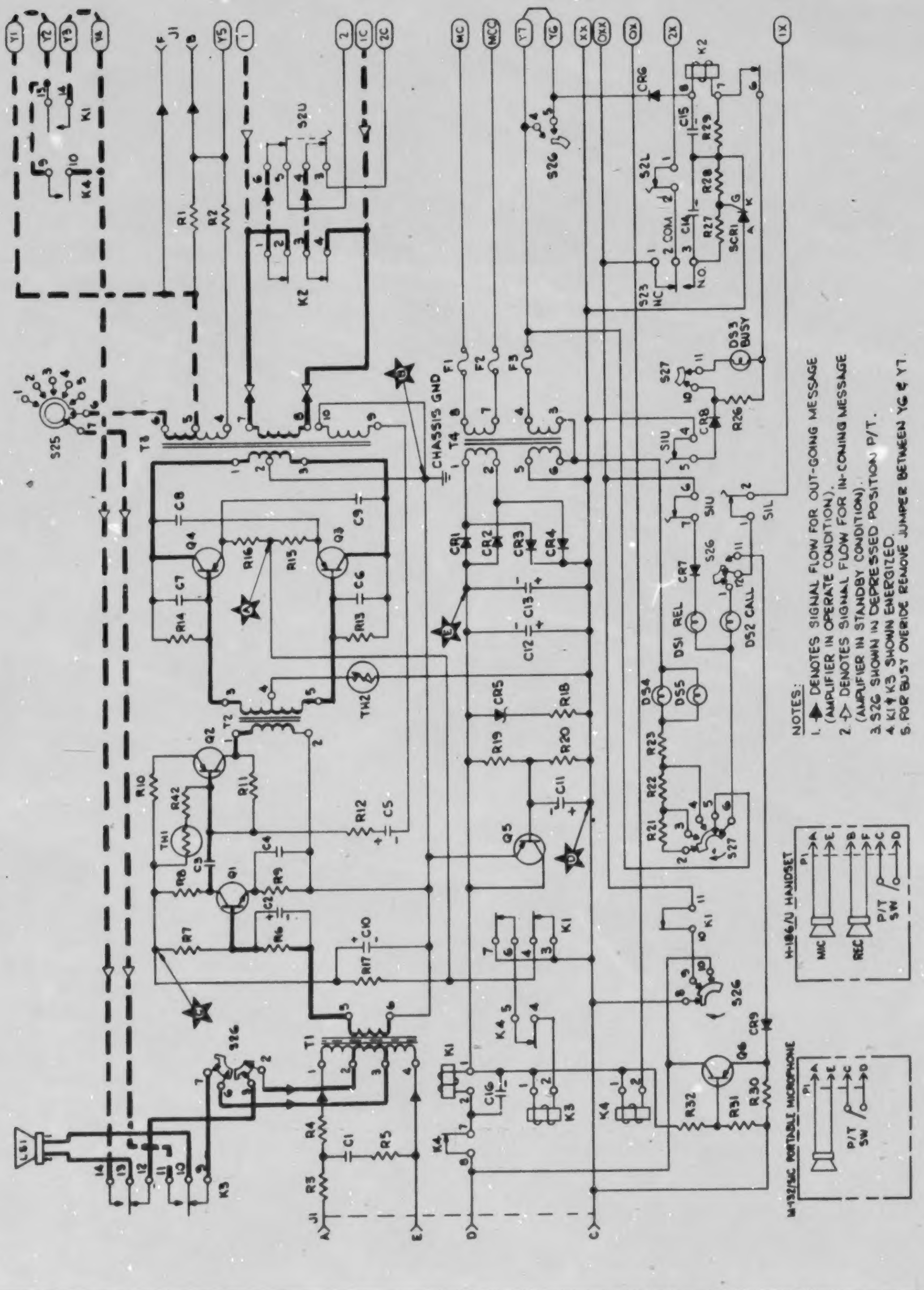
PUBLIC ADDRESS SETS

Public address sets are used at fleet landings and in amphibious operations to direct the movement of personnel, vehicles, and small boats; to communicate between ships and small boats; and to address personnel aboard ship where high noise levels are present or where the installed announcing is inoperative or impractical. They are also used for entertainment, and such functions as church services, wardroom and ready room briefings, change-of-command and other ceremonies, and personnel training. The two types of public address sets are the electronic megaphone type, and the portable amplifier or lectern type.

PUBLIC ADDRESS SET AN/PIC-2

The AN/PIC-2 is an electronic megaphone type public address set designed to perform under extremes of temperature and high humidity. The driver unit, microphone, amplifier enclosure, and battery enclosure are watertight. The set consists of a loudspeaker horn, a microphone, a transistor amplifier assembly, a driver unit, eight D-size batteries, and a pistol-grip handle with a press-to-talk switch, battery selector switch, and external battery connector. All components are housed in one assembly, (fig. 8-32). A 15-foot external power cable is provided for connecting the set to an external 12-volt battery when desired.

To operate the set, put the battery selector switch to the INT. position (or to the EXT. position if operation is to be from external battery). Grasp the pistol-grip handle with one hand and raise the unit so that the rubber microphone is almost touching the mouth, and direct the horn in the direction it is desired to communicate. Press the press-to-talk switch and speak directly into the microphone in a strong voice. Release the press-to-talk switch when the message is completed. The set is specially designed to eliminate acoustic feedback to the extent possible. Acoustic feedback may occur however, if the horn is directed toward a reflecting surface such as a deck or bulkhead. When using the set below decks, back the volume

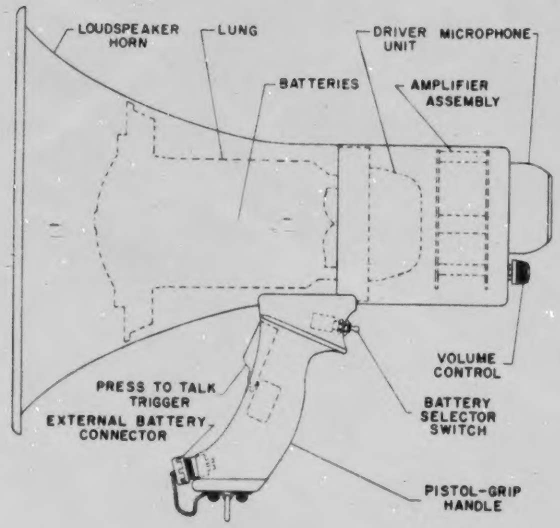


S25
T3
T1
T2
T4
K1
K2
K3
K4
S26
S2U
S2L
S23
S27
S1U
S1L
Q1
Q2
Q3
Q4
Q5
Q6
TH1
TH2
LS1
J1
CHASSIS GND
DS1 REL
DS2 CALL
DS3 BUSY
DS4
DS5
SCR1
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
F1
F2
F3
Y1
Y2
Y3
Y4
Y5
Y6
Y7
1C
2C
MC
MCC
XX
OXX
OX
2X
1X
H-186/U HANDSET
MIC
REC
P/T SW
P1
M-132/SC PORTABLE MICROPHONE

NOTES:
1. ➡ DENOTES SIGNAL FLOW FOR OUT-GOING MESSAGE (AMPLIFIER IN OPERATE CONDITION).
2. ⇨ DENOTES SIGNAL FLOW FOR IN-COMING MESSAGE (AMPLIFIER IN STANDBY CONDITION).
3. S26 SHOWN IN DEPRESSED POSITION P/T.
4. K1 & K3 SHOWN ENERGIZED.
5. FOR BUSY OVERIDE REMOVE JUMPER BETWEEN Y6 & Y7.

140.128

Figure 8-31.—Overall functional diagram.



27.295
Figure 8-32.—Public address set AN/PIC-2.

control knob off until feedback stops, then advance it gradually to a point where maximum volume without feedback is obtained.

Amplifier Circuits

The transistor amplifier is a three-stage transformer coupled type. It consists of a volume control, R1, input transistor, Q1, interstage transformer, T2, push-pull power transistors Q3 and Q4, and an output inductor L1 (fig. 8-33).

Transistors Q1 and Q2 are biased for class A operation, and Q3 and Q4 operate in class AB. The output stage bias network includes thermistor assembly RT1, to temperature stabilize transistors Q3 and Q4 at high operating temperatures. For further stabilization, each stage includes an emitter resistor. The driver and output stages each have reverse feedback from collectors to bases, the feedback resistor in each case being also part of the d-c bias network. In addition, reverse feedback over two stages is provided through C3 and R8, from the collector of Q3 to the base of Q2.

The base circuits of the output stage normally have a small negative d-c bias applied through the bias network resistors, adjusted so that the no-signal collector current of this stage is small. Temperature rise in the transistors tends to increase this current. To prevent this current increase, the thermistor resistance decreases with increasing temperature, thus reducing the negative bias and keeping the no-signal collector current small.

D-C Power Circuits

The 12-volt d-c supply is selected from either the internal or external batteries by the battery selector switch S2. The press-to-talk switch S1 supplies d-c power to the amplifier only while the switch is held closed.

The current drain is very small when S1 is closed and no signal is applied to the microphone. The current is maximum when the loudest-signal is being amplified, as the collector current of the output stage varies with the strength of the amplified signal.

Microphone and Loudspeaker Assemblies

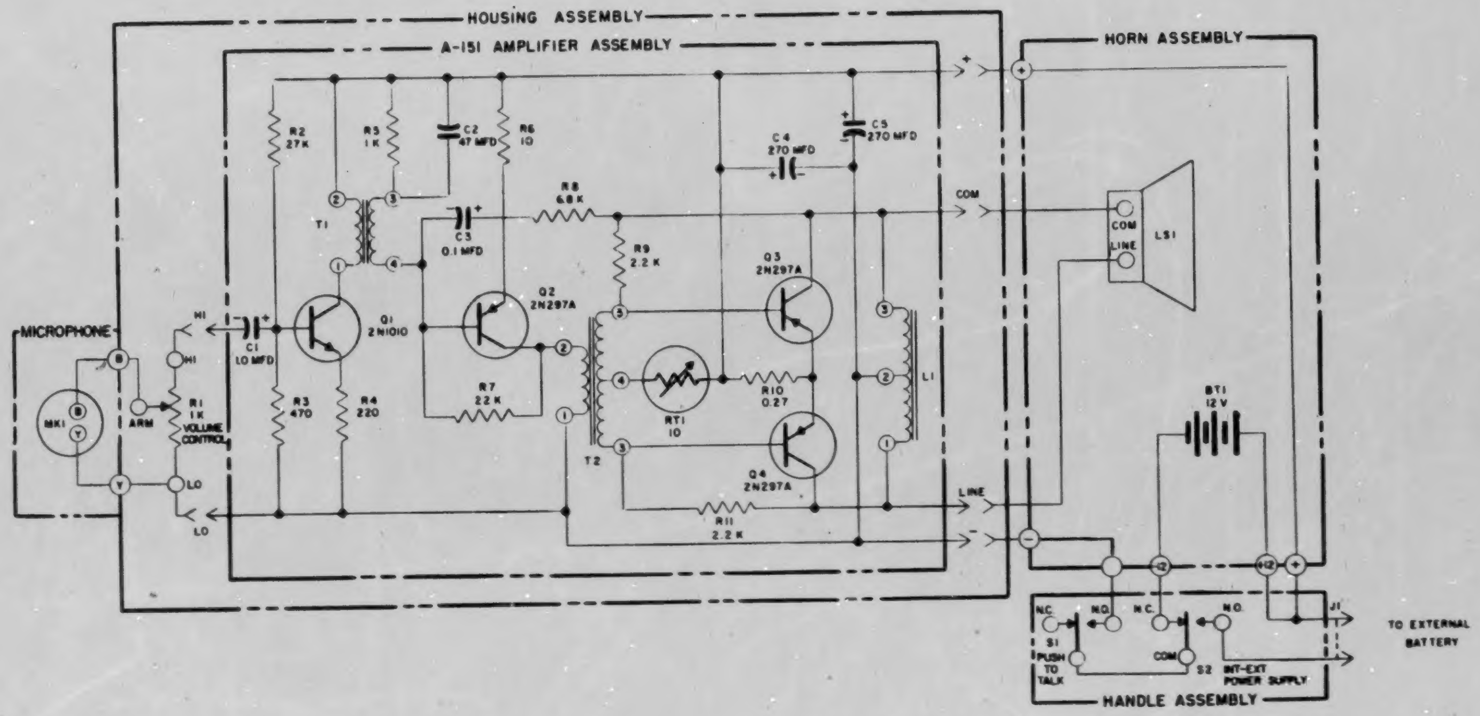
The MK1 magnetic microphone has an impedance of approximately 150 ohms. The microphone output is applied to transistor Q1 through the volume control R1, and capacitor C1. A selected portion of the sound radiated to the rear by the loudspeaker horn acts on the back of the microphone diaphragm. This sound is phased so as to reduce acoustic feedback.

Loudspeaker LS1 is a moving coil permanent magnet type. Amplifier output signals actuate the voice coil and diaphragm, and the resulting sound waves are amplified and directed by the loudspeaker horn.

Maintenance

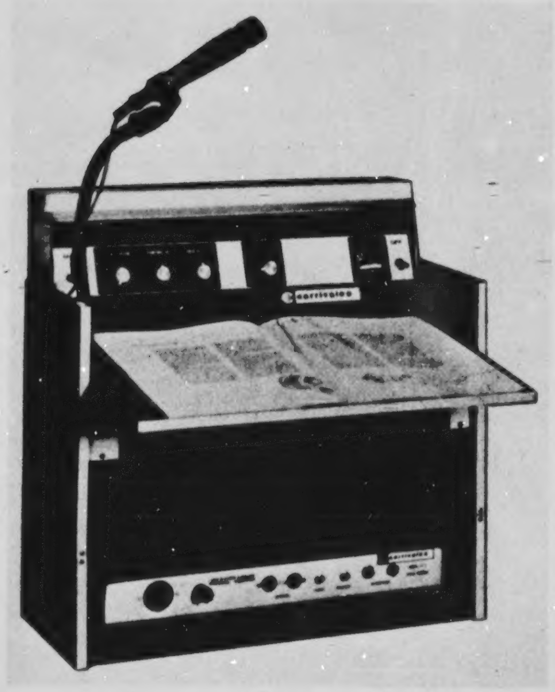
Preventive maintenance consists of replacing batteries, and routine cleaning and inspections. When the batteries are replaced, inspect the battery contact springs and clean if necessary. If the springs are badly corroded they should be replaced. Keep the external power cable free of dirt and corrosion. Clean the spring clips with sandpaper and apply a thin coat of petrolatum to reduce corrosion. Inspect the connector and clean if necessary.

Periodically check the microphone housing. Keep the opening to the microphone free of dust, dirt, oil, grease, salt crystals or other foreign matter. Salt crystals left by the evaporation of salt water and spray should be dissolved and rinsed away with fresh water, then the parts dried with a soft cloth.


HOUSING ASSEMBLY
A-151 AMPLIFIER ASSEMBLY
HORN ASSEMBLY
HANDLE ASSEMBLY
MICROPHONE
MK1
B
Y
HI
LO
ARM
R1 1K VOLUME CONTROL
C1 10 MFD
R2 27K
R3 470
R4 220
R5 1K
C2 47 MFD
R6 10
T1
Q1 2N1010
C3 0.1 MFD
R8 6.8K
R7 22K
Q2 2N297A
R9 2.2K
T2
RT1 10
R10 0.27
Q3 2N297A
Q4 2N297A
R11 2.2K
C4 270 MFD
C5 270 MFD
L1
COM
LINE
LS1
BT1 12V
+
−
+12
−12
N.C.
N.O.
S1 PUSH TO TALK
COM
S2 INT-EXT POWER SUPPLY
J1
TO EXTERNAL BATTERY

140.48

Figure 8-33.—Public address set AN/PIC-2, schematic diagram.



27.296X
Figure 8-34.—Public address set, lectern type.

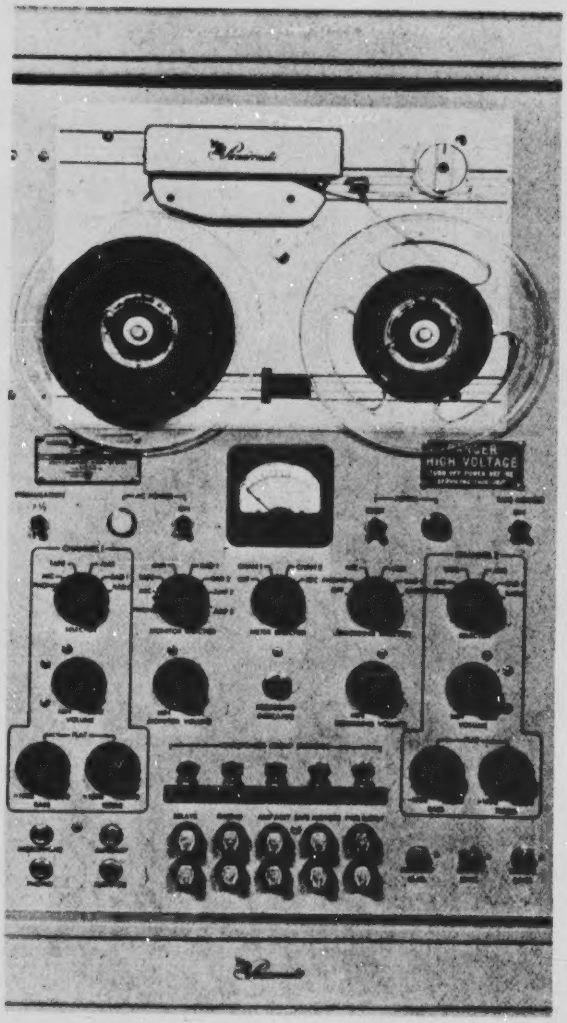
Check the inside of the pistol-grip handle occasionally. Remove the handle cover and inspect the switch contacts. Clean if necessary.

The manufacturer's technical manual contains detailed instructions for troubleshooting and repair of the set. All components are designed for easy replacement.

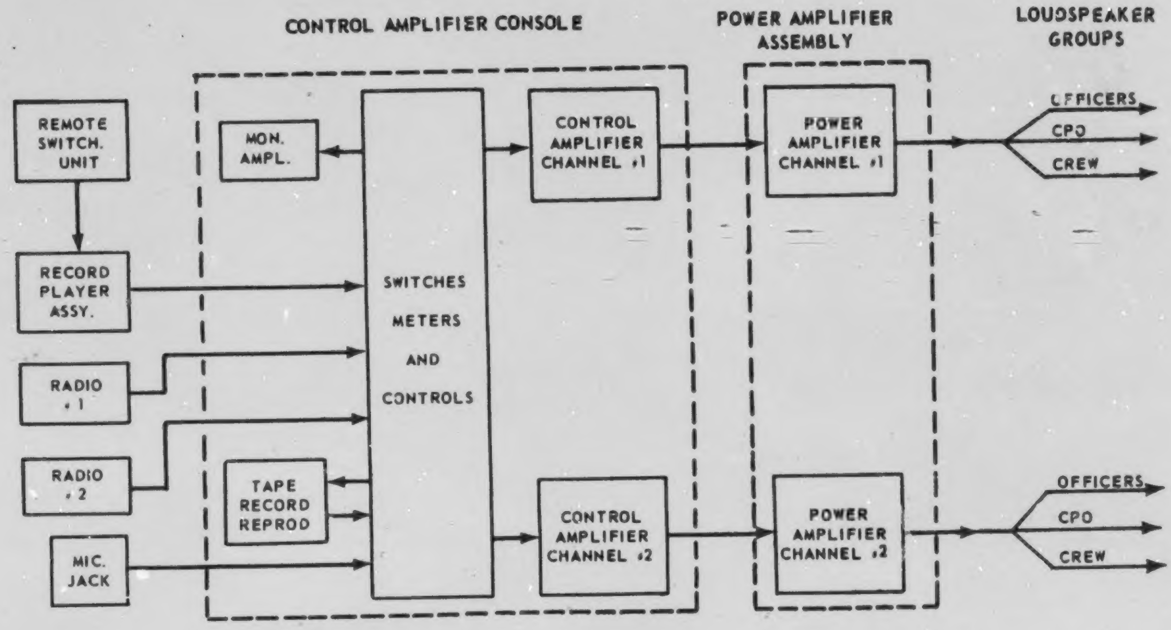
PUBLIC ADDRESS SET, LECTERN TYPE

Modern Navy ships are provided with the lectern type public address set. This set (fig. 8-34) is a portable self-contained unit capable of reproducing sound for entertainment or dissemination of information. The set consists of an illuminated reading counter with a removable unidirectional dynamic microphone, a transistorized amplifier and controls, an extended range loudspeaker, a battery meter, and jacks for microphones, record player, tape recorder, and two external speakers. Power to operate the set is provided either by the self-contained dry battery, or an external 115-volt, a-c supply.

As an IC Electrician, you may be assigned the responsibility for setting up and checking out public address sets. To allow time for any minor adjustments or repairs that may be required, always check the set or system out well in advance of the time it is to be used.



27.340
Figure 8-35.—Control amplifier console.


CONTROL AMPLIFIER CONSOLE
POWER AMPLIFIER ASSEMBLY
LOUDSPEAKER GROUPS
REMOTE SWITCH. UNIT
MON. AMPL.
CONTROL AMPLIFIER CHANNEL #1
POWER AMPLIFIER CHANNEL #1
OFFICERS
CPO
CREW
RECORD PLAYER ASSY.
SWITCHES METERS AND CONTROLS
RADIO #1
RADIO #2
TAPE RECORD REPROD
MIC. JACK
CONTROL AMPLIFIER CHANNEL #2
POWER AMPLIFIER CHANNEL #2
OFFICERS
CPO
CREW

27.339

Figure 8-36.—Basic block diagram of circuit SE.

SHIP'S ENTERTAINMENT SYSTEM

A separate shipboard announcing system, circuit SE, is used primarily for the entertainment of ship's company. This nonvital, readiness class 4 system is capable of reproducing, amplifying, and retransmitting, commercial radio broadcasts, tape recordings, and voice announcements.

COMPONENTS

The system, as installed on a destroyer class, consists of four major components and associated speaker groups. These components; The Control Amplifier Console, Automatic Record Player Assembly, Power Amplifier, and Remote Switching Control Unit are usually located in the forward IC room; however, on occasion they may be located remotely either together or individually. Two radio receivers are also associated with the system, generally they are located near the Control Amplifier console.

The Control Amplifier Console houses a tape recorder reproducer (3.5 or 7.0 in. per minute), two channel line amplifiers (20 watt), an amplifier for monitoring, and the necessary switches, meters, and controls to operate the system. It is from this console that program selection is made and from here that any voice announcements originate. A Control Amplifier Console is shown in figure 8-35.

The Power Amplifier consists of two amplifiers (50 watt) and serves to boost the output of the control amplifier for presentation to three individual speaker groups. The loudspeakers are divided into Officer, Chief Petty Officer, and Crew groups.

The Automatic Record Player Assembly and the Remote Switching Unit are used to reproduce commercial phonograph recordings. Operating in conjunction with these units allows playing of 52 recording (104 selections) of the 45 rpm variety. The Record Player Assembly in addition to the record playing function, contains components which preamplify the signal, stop the entire unit, supply the needed power, and reject unwanted recordings.

The Remote Switching Control Unit contains the necessary switches (pushbutton) and circuitry to select the desired recording to be played.

OPERATION

Any input may be distributed over either channel or both channels simultaneously. Refer to the block diagram (fig. 8-36). Two different inputs may be distributed at the same time, one over each channel. Either channel may be monitored. Tape recordings may be made with both channels in operation either from the input being distributed or from another source (not shown). Inputs may be attained from the two external radio receivers, the automatic record player, the installed tape recorder-reproducer or from the remote microphone jack. This jack can be used in conjunction with a portable record player or tape record-reproducer.

Two channels are initially installed at each loudspeaker. Selection is made by a channel selector located there. A volume selector is also located on the speaker. The operator at the Control Amplifier Assembly selects speaker groups in operation, Officer, Chief Petty Officer, or Crew.

The system receives its power from the forward IC switchboard.

Maintenance

The entertainment system is of primary interest to the entire ship's company as it is often the only source of information and news. Through proper planned maintenance prodedures, casualties can be kept to a minimum.

The elaborate switching employed in the system makes it easy to troubleshoot. Generally, the system can be kept at least partially in operation during maintenance and repair evolutions.

Programming

Although this system is often located in the IC room it is of paramount importance that the entire ship's company be permitted to use it. Working together with the electrical officer, IC Electricians should draw up specific programs that will satisfy most of ship's company.

The IC Electrician who indiscriminately shifts programs and imposes his taste in entertainment upon the rest of the crew soon finds himself at odds with his messmates and his seniors. Once a program has been planned and approved, it should be adhered to as closely as possible.

CHAPTER 9

DIAL TELEPHONE SYSTEMS, PART I

In addition to sound-powered telephone circuits, dial telephone systems are installed on the Navy's combatant ships. The dial telephone system, or circuit J, is primarily an administrative circuit that provides complete selective telephone communication throughout the ship. This system is also used to supplement other communication facilities for ship control, fire control, and damage control. The capacity of the system varies with the size and needs of the particular ship.

This chapter describes the equipment and operating principles of the so-called Strowger system, a typical shipboard dial telephone system manufactured by the Automatic Electric Company.

TELEPHONE EQUIPMENT

A telephone system consists of a group of telephones with lines so arranged at a central point that any two telephones in the system can be interconnected. In an automatic telephone system, the connections between the telephones are completed by remotely controlled switching mechanisms. In a manual telephone system, the connections between the telephones are completed by a switchboard operator.

The switching mechanisms in an automatic system are controlled at the calling telephone by a device, or dial on the telephone instrument. The dial has 10 digits, any one of which can be dialed. When the dial is operated it causes a series of interruptions, or impulses, in a current flowing in the line circuit. The number of impulses sent out by the dial corresponds to the digit dialed. These impulses cause the automatic switches to operate and to select the called telephone.

The dial telephone system (fig. 9-1) consists of: (1) telephone station equipment, made up of telephone instruments which may receive or initiate calls; (2) automatic switchboard equipment that includes the switching necessary to interconnect the line stations; (3) power equipment that furnishes normal and emergency power for the system, and (4) accessory equipment used to interconnect the ship's exchange with shore exchanges when the ship is in port.

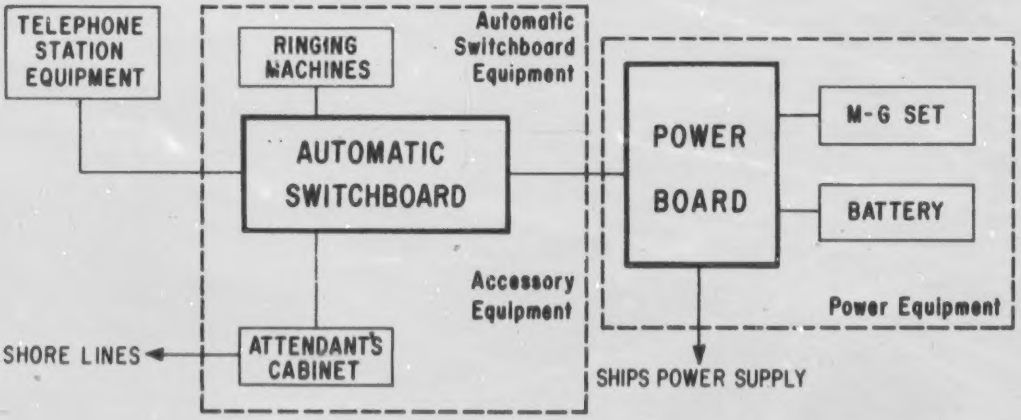
TELEPHONE STATION EQUIPMENT

The telephone station equipment consists of different types of telephone instruments, each type designed for use in weather-protected (below decks) or exposed (weatherdecks) locations. The telephone instrument is a compact unit which transmits and receives speech, and signals the desired station. It comprises a transmitter, receiver, dial and ringer. The transmitter changes sound into an undulating current that is sent over an electrical circuit. The receiver changes the undulating current back into sound. The dial, when operated, causes a series of interruptions (impulses) in the current flowing in the line circuit. The ringer provides an audible signal when the station is called. Remote ringing devices that contain a power-signal relay and a horn, bell, or siren are used in high noise-level locations, such as machinery spaces.

TYPES OF TELEPHONES

The types of telephones furnished with the dial telephone system are illustrated in figure 9-2. The types differ mainly in the form in which the components are assembled. The components perform the same function, but the form and mounting for each type is of special design and depends on whether the instrument is to be used in a protected or an exposed location.

The TYPE A desk set telephone (fig. 9-2A) is installed in staterooms, cabins, offices, and similar stations. The desk set consists of a phenolic case (containing the ringer, dial and other working parts), a handset, and connecting cord with a terminal block for making the line connections.



7.76(140B)

Figure 9-1.—Block diagram of the dial telephone system.

The TYPE F bulkhead telephone (fig. 9-2B) can be installed in any station except those on weather decks. The type F telephone is a nonwatertight unit designed for mounting on a bulkhead or on the side of a desk. It consists essentially of a metal housing on which are mounted the handset, dial, and ringer. The line connections are made at a terminal block inside the housing.

The TYPE C splashproof telephone (fig. 9-2C) is installed at stations on weather decks and other stations exposed to moisture. The type C telephone is designed for bulkhead mounting and consists essentially of a metal housing on which are mounted the handset and dial which are enclosed in a splashproof box. The connections to the line are made at a terminal strip inside the housing.

The TYPE G bulkhead telephone (fig. 9-2D), previously installed only on submarines, is now being installed aboard surface ships, and is interchangeable electrically with the type F. The type G, which is panel mounted, is furnished also in two other enclosures. The type G (desk) is interchangeable with the type A and the type G (watertight) is interchangeable with the type C.

The main assemblies that comprise a telephone instrument are the handset and base.

HANDSET

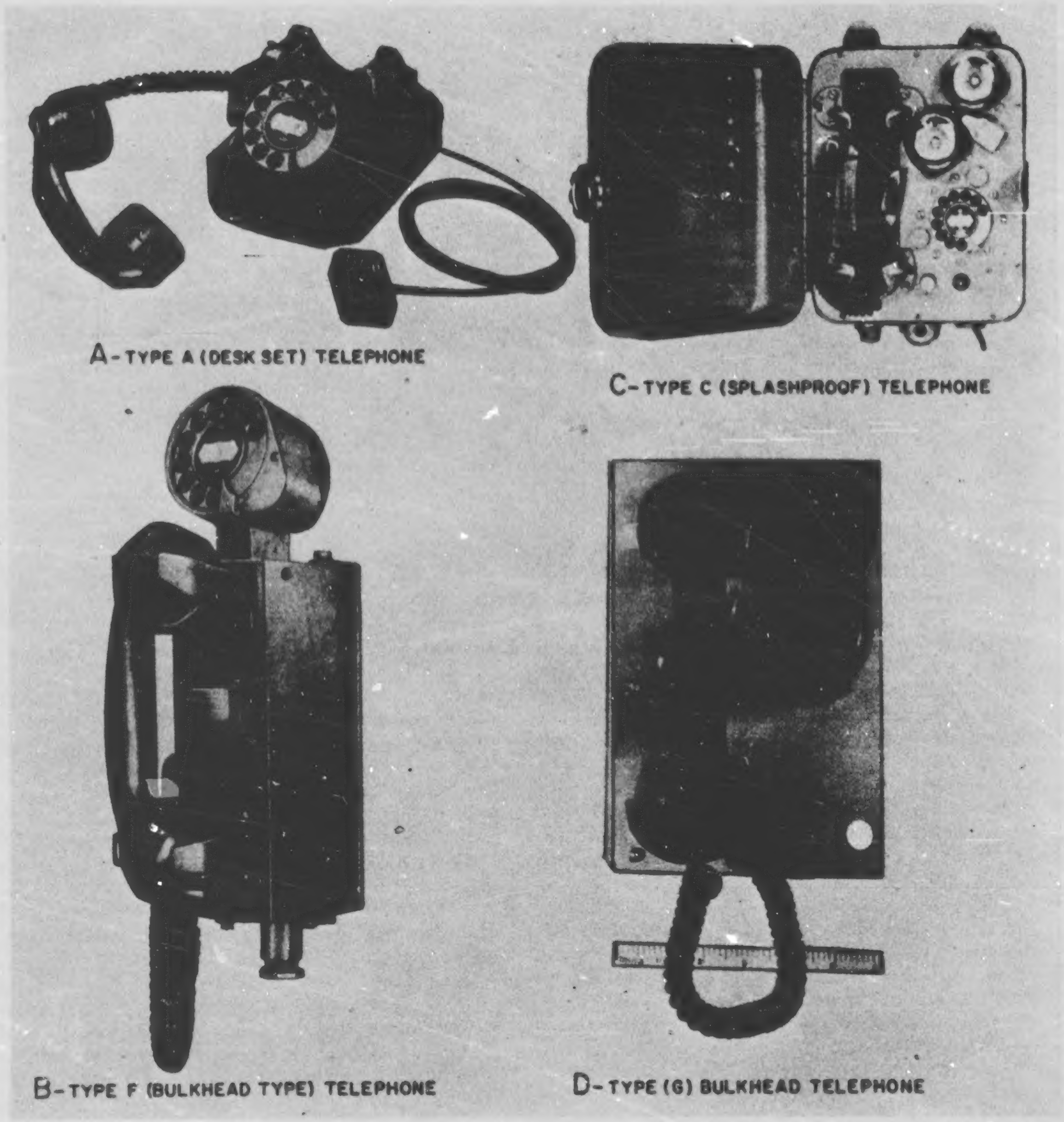
The standard handsets (fig. 9-3), consist of a conveniently shaped handle with two mounting cups, one for the transmitter and the other for the receiver. The mounting cups are at an angle with the handle to bring the transmitter the proper distance from the lips, for the average user, when the receiver is centered on the ear.

The transmitter and receiver are held in the mounting cups by an ear cap for the receiver and a mouthpiece for the transmitter. Both retaining pieces screw on the handset handle. In order to prevent the possibility of inserting the transmitter into the receiver mounting cup and vice versa, the transmitter is made to fit only into the transmitter cup, and the receiver to fit only into the receiver cup.

The transmitter and receiver units are both of the capsule type. Connections from the cord conductors are brought out to contact spring clips in the mounting cups of the handset. The connection between the transmitter or receiver unit and the cord conductors is completed when the capsule is in contact with the contact spring clips.

Transmitter

The transmitter unit consists essentially of a metal diaphragm and an insulating cup containing loosely packed carbon granules. As soon as the handset is removed from the cradle, or hook switch, direct current supplied by the common battery at the switchboard flows through the transmitter. The diaphragm is mechanically connected to the carbon button so that sound waves striking the diaphragm cause it to vibrate.



A-TYPE A (DESK SET) TELEPHONE

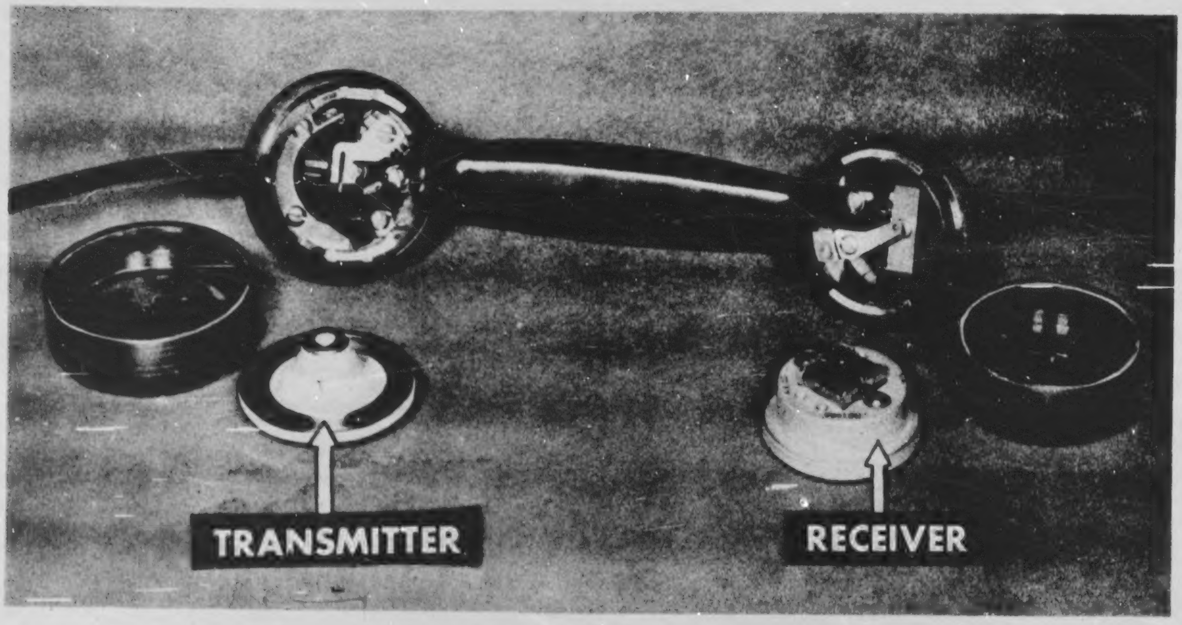
C-TYPE C (SPLASHPROOF) TELEPHONE

B-TYPE F (BULKHEAD TYPE) TELEPHONE

D-TYPE (G) BULKHEAD TELEPHONE

7.83

Figure 9-2.—Telephones.



3.198

Figure 9-3. — Telephone handset.

The mechanical movements of the diaphragm are transmitted to the carbon granules. When the carbon granules are compressed by an inward movement of the diaphragm, the resistance is lowered and more current flows through the transmitter. When the diaphragm relaxes, the pressure on the carbon granules is reduced, the resistance is increased, and less current flows. Thus, as long as the diaphragm is vibrating from the sound waves, the resistance of the carbon granule chamber is constantly changing, which in turn causes the current through the transmitter to undulate accordingly. This undulating current, called the VOICE CURRENT, is sent out on the telephone line after being boosted by the action of the induction coil and talking capacitor (explained later). The receiver at the other end of the line converts the voice current back into sound waves.

Receiver

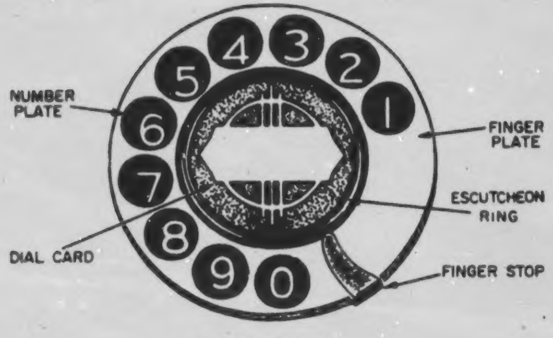
The receiver unit is of the permanent magnet polarized type. It consists essentially of a powerful permanent magnet with two soft-iron coil-wound pole pieces and a diaphragm contained in a protective shell. The diaphragm is mounted under a slight tension so that it is pulled toward the pole pieces by the permanent magnet. The voice currents, flowing through the coils about the two pole pieces, set up magnetomotive forces that alternately aid and oppose the magnetic flux of the permanent magnet. This action causes the receiver diaphragm to be attracted with alternately greater and lesser force. As the diaphragm moves back and forth it reproduces the vibrations of the distant transmitter, and the sound waves thus produced are heard at the receiver.

Base

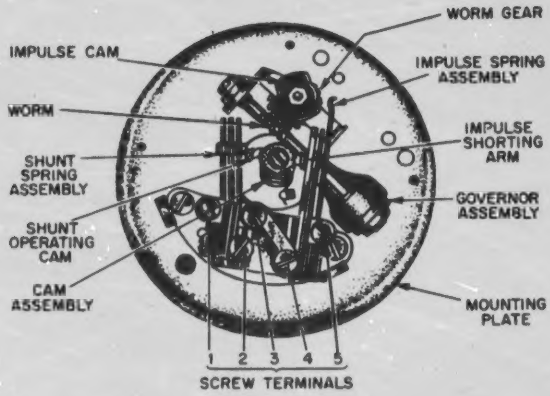
The base includes the dial, hook switch, ringer, two capacitors, and induction coil. The telephones (fig. 9-2) include the same combination of parts and assemblies, but the bases on which the parts are mounted differ somewhat, and the mounting arrangement differs considerably.

Dial

The dial (fig. 9-4) enables the calling party to control the automatic switching mechanisms


NUMBER PLATE
FINGER PLATE
ESCUTCHEON RING
DIAL CARD
FINGER STOP
1
2
3
4
5
6
7
8
9
0

A. FRONT VIEW


WORM GEAR
IMPULSE CAM
IMPULSE SPRING ASSEMBLY
WORM
IMPULSE SHORTING ARM
SHUNT SPRING ASSEMBLY
GOVERNOR ASSEMBLY
SHUNT OPERATING CAM
CAM ASSEMBLY
MOUNTING PLATE
1
2
3
4
5
SCREW TERMINALS

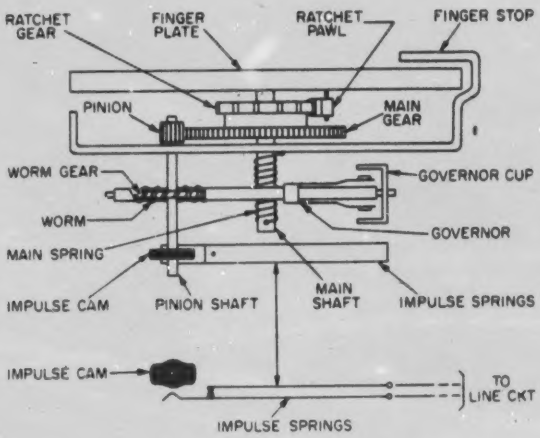
B. REAR VIEW

7.85

Figure 9-4.—Telephone dial.

by a series of interruptions, or impulses, in the current flow. The number of impulses sent out by the dial corresponds to the digit dialed. The principal functions of the dial are to (1) deliver impulses to the line, (2) short-circuit the parts of the telephone that introduce unnecessary resistance in the dialing circuit, and (3) prevent the dialed impulses from clicking in the receiver.

The principal parts and assemblies of the dial are compactly assembled on a mounting plate (fig. 9-4). These parts and assemblies are (1) finger plate (with 10 holes), (2) number plate, (3) governor assembly, (4) impulse cam and springs, (5) impulses shorting arm, (6) shunt cam and springs, and (7) driving mechanism. The dial parts and assemblies are arranged so that when the dial is operated, the line is opened and closed at a rate of approximately 10 interruptions per second.

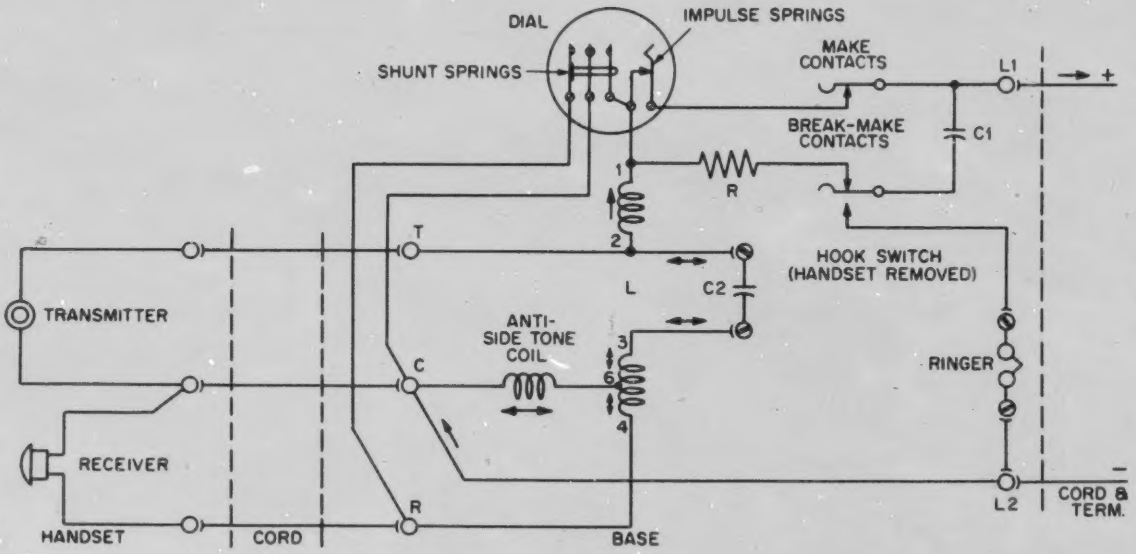

RATCHET GEAR
FINGER PLATE
RATCHET PAWL
FINGER STOP
PINION
MAIN GEAR
WORM GEAR
GOVERNOR CUP
WORM
GOVERNOR
MAIN SPRING
IMPULSE CAM
PINION SHAFT
MAIN SHAFT
IMPULSE SPRINGS
IMPULSE CAM
TO LINE CKT
IMPULSE SPRINGS

7.86

Figure 9-5.—Telephone dial schematic.

The finger plate is fitted to the main shaft, which rotates when the dial is turned from any number to the finger stop (fig. 9-4). Thus, as the main shaft rotates, the tension of the main spring, which is also mounted on the main shaft, is increased to provide the power needed to return the dial (main gear) to normal when the finger plate is released. When the dial is turned from normal, the ratchet pawl (fig. 9-5) slips over the ratchet gear which is mounted on the main shaft with the main gear. This prevents the main gear from rotating. When the dial restores to normal, however, the ratchet pawl engages the ratchet gear and the main gear rotates.

The speed of the dial mechanism as it returns to normal under the spring tension is controlled by the GOVERNOR ASSEMBLY. The governor assembly consists of a worn gear shaft that is mechanically connected to the main gear of the dial through a gear train (fig. 9-5). Two flyball wings are attached to the worn gear shaft. A governor weight on the end of each flyball wing protrudes into the governor cup. The rotary motion of the shaft causes the flyball wings to attempt to fly outward and due to centrifugal force, friction is set up between the governor weights and the governor cup. The speed of the dial is thus regulated by adjusting the flyball wings to increase or decrease the amount of pressure the governor weights exert on the inside surface of the cup.



7.87

Figure 9-6.—Schematic diagram of C telephone.

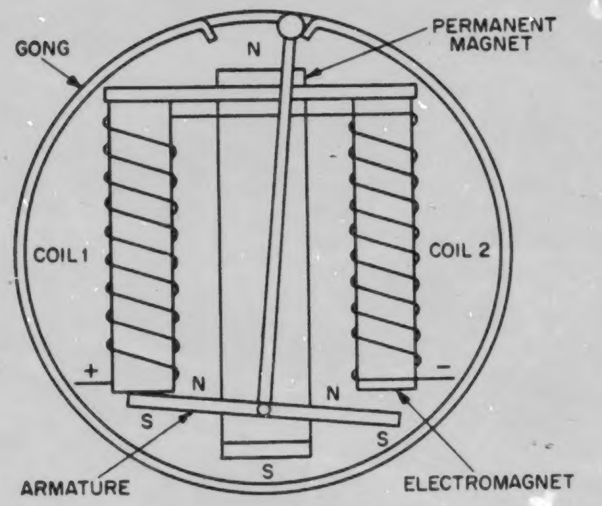
The IMPULSE CAM is geared mechanically to the main gear through a gear train (not shown) so that the impulse cam is caused to rotate during the time the dial mechanism is being returned to normal. The impulse springs are normally closed and are opened intermittently by the impulse cam only when the dial is returning to normal. An impulse is produced each time the impulse springs are opened. The travel from any off normal position is one series of impulses. The number of impulses in the series depends on how far the dial is turned away from normal. As the impulse cam rotates it opens the impulse springs, and thus the line circuit, the same number of times as the digits dialed. The momentary opening of the line circuit produces the dial impulses that actuate the automatic switching mechanism (Strowger switches) at the telephone switchboard to extend the connection to the line associated with the dialed number.

The dial has a time delay feature that separates the series of dial impulses. The time delay is the time between the last impulse of a series and the complete restoring of the dial. It is approximately equal to the time required for one impulse and is accomplished by the movement of the impulse springs away from the cam by the cam shunt assembly. The last time the cam passes, no impulse is produced. The purpose of the delay feature is to allow the relays in the automatic switchboard to operate properly between each series of impulses.

The SHUNT OPERATING CAM (fig. 9-4) is mounted on the main shaft. When the dial is at normal, the shunt cam holds the shunt springs in the normally open position. When the dial is turned off normal, the shunt cam is moved out of engagement with the shunt spring assembly and the shunt springs close to shunt the receive and transmitter. The closure of the shunt springs prevents the inpulses from being heard in the receiver during dialing, and also prevents the variable resistance of the transmitter from affecting the character of the dial impulses.

Hook Switch

A representative telephone station circuit is illustrated in figure 9-6. It is not desirable to have both the talking apparatus (transmitter and receiver) and the signaling apparatus (ringer and capacitor, C1) connected to the line while the telephone is in use. Accordingly, the hook switch, also called the cradle switch, monophone



7.88

Figure 9-7.—Polarized ringer.

switch, or plunger switch (fig. 9-6) is an assembly of springs arranged so that removing or replacing the handset brings about the desired circuit changes. When the handset is placed on the hook switch, the ringer is connected to the line through C1, and the transmitter, receiver, and dial are disconnected from the line. When the handset is removed from the hook switch, a pair of make contacts and a set of break-make contacts on the switch (1) connect the transmitter, receiver, and dial to the line; (2) disconnect the ringer from the line; and (3) connect C1 across the dial impulse springs. The hook switch on all types of telephones has the same function, but the mechanical arrangement differs.

Ringer

The ringer (fig. 9-7) is of the polarized, untuned type commonly called the STRAIGHT-LINE ringer (bell). It is suitable for use on both individual and party lines and is called UNTUNED because it will operate over a wide range of frequencies.

The ringer consists of a hard-steel permanent magnet, a soft-iron electromagnet, a pivoted armature carrying a clapper rod and clapper, and a gong or set of gongs. The electromagnet is U-shaped with a coil around each leg. The soft-iron armature is pivoted at its center, and lies in front of the two poles of the electromagnet, but does not quite complete the magnetic circuit. The permanent magnet is used to polarize the armature ends of the electromagnet. The armature end of each coil has a consequent north polarity produced by the permanent magnet. The two ends of the armature have consequent south poles produced by the permanent magnet.

The coils are wound on the pole pieces so that when current flows in one direction (fig. 9-7) the mmf of coil 1 aids the permanent magnet flux and the mmf of coil 2 opposes it. Thus, coil 1 increases the strength of the north pole at the armature end of coil 1 and coil 2 attempts to establish a south pole at the armature end of coil 2. Because like poles repel and unlike poles attract, the armature moves clockwise and the clapper strikes the gong at the right.

When the ringer current reverses, the mmf of the coils reverses. Thus, coil 2 strengthens the north pole at the armature end of coil 2 and coil 1 attempts to establish a south pole at the armature end of coil 1. The armature moves counterclockwise and the clapper strikes the gong at the left. The gongs ring once for each half cycle of ringing current. The ringing current is 17 to 25 hertz.

When no current flows through the coils, the armature south poles attract the north poles at the armature end of the coils and the clapper moves either to the right or the left depending on which air gap is the shortest. A biasing spring (not shown) is provided to give the armature a definite position when the gongs are silent. This spring holds the clapper against one gong and prevents the gong from tingling when the other party on the line is dialing (biasing springs on commercial telephones prevent clapper operation when the wrong polarity of ringing current is received in selective ringing on four-party lines). Small pieces of nonmagnetic material are placed between the core end and the armature to prevent actual contact and subsequent sticking due to residual magnetism.

Capacitors

Two capacitors are used in the telephone, one in the ringing circuit and one in the transmission circuit (fig. 9-6). The capacitor C1 in the ringing circuit allows a-c ringing current to pass through the ringer and prevents the flow of direct current. During dialing C1 (in series with R) is shunted across the dial impulse springs to minimize sparking and suppress radio interference. The capacitor C2 in the transmission circuit improves the transmission output characteristics of the telephone. If capacitor C2 were not used, the output would be very low because of the high impedance of the telephone circuit and the line circuit. The action of C2 is explained later.

Induction Coil

The induction coil L couples the transmitter and receiver units to the line (fig. 9-6). It also increases the output volume by boosting the voice current undulations developed by the transmitter and prevents or decreases SIDETONE. Sidetone occurs when a person hears his own voice in the receiver while talking into the transmitter.

The induction coil L consists of three windings (1-2, 3-6, and 6-4) on a laminated iron core. The windings are magnetically interlinked by the common magnetic circuit provided by the iron core. The induction coil serves as a 3-winding autotransformer in which part of the winding is common to both the primary (input) and the secondary (output) circuits. Any change in the current in one of the windings causes a corresponding induced emf in all three windings. The core is made up of high permeability laminations to provide a low reluctance path for the magnetic flux. A small air gap in the magnetic circuit prevents saturation of the core by the direct current feeding the transmitter.

TELEPHONE CIRCUIT

A telephone circuit (fig. 9-6) comprises the ringing, dialing, transmission, and receiving circuits. Booster and antisidetone features are also included in the circuit. Note that the handset is removed from the hook switch so that the transmitter, receiver, and dial are connected to the line, and the ringer is disconnected from the line.

Ringing Circuit

The ringing circuit consists of line L1, ringing capacitor C1, make-contacts on the hook switch, the ringer, and line L2, (fig. 9-6). This circuit condition exists when the handset is placed on the hook switch. When the handset is removed from the hook switch, the ringing capacitor C1 is transferred from the ringer to the dial impulse springs, as previously mentioned, to prevent excessive sparking at the contacts of the impulse springs.

Dialing Circuit

The dialing circuit consists of line L1, the hook switch, the dial impulse springs (shunted by resistor R and capacitor C1, in series), the dial shunt springs, and line L2 (fig. 9-6). When the dial is operated, the dial shunt springs close to shunt the transmitter, receiver, and induction coil so that they will not affect the impulses sent out by the dial.

Transmission Circuit

The transmission circuit includes two distinct circuits, the main talking circuit, and the local talking circuit. The MAIN TALKING CIRCUIT consists of line L1, winding 1-2 of the induction coil, the transmitter, and line L2 (fig. 9-6). The LOCAL TALKING CIRCUIT consists of the transmitter, capacitor C2, winding 3-6 of the induction coil, and the antisidetone coil (fig. 9-6). This circuit is designated "local" because the circuit is completed within the individual telephone and not through the line conductors.

The main talking circuit is also the d-c path through the telephone. The direct current for the transmitters of the calling and called telephones is furnished by the automatic switchboard through relays associated with the connector switch (not shown) which establish the connection.

When talking into the transmitter, two sets of current undulations are set up: (1) those directly produced in the line due to the variations in the resistance of the transmitter; and (2) those produced in the local talking circuit by the charging and discharging of capacitor C2, caused by the varying potential drop across the transmitter.

The local talking circuit current undulations are best understood if it is kept in mind that the capacitor C2, is connected across the transmitter, directly on one side and through winding 3-6 of the induction coil and the antisidetone coil on the other side. Thus, the resistance variation introduced by the action of the transmitter causes the voltage to vary on the plates of capacitor C2. Alternating currents will then flow in the local talking circuit as the capacitor C2 adjusts the charge on its plates to the varying difference of potential across the transmitter.

The resulting alterating currents flowing in winding 3-6 of the induction coil, considered as the primary of the autotransformer, will induce voltages in the secondary winding 1-2. The change in current that occurs in winding 1-2 is of greater magnitude as a result of the change of produced current in winding 3-6 by the transmitter. The induced voltage in winding 1-2 aids the voice currents directly delivered to the line via the main talking circuit and thus a BOOSTER feature is achieved.

It is important that the transmitter of the calling telephone produces a large effect on the receiver of the called telephone and little or no effect on the local receiver. Accordingly, the telephone circuit is designed so that the local transmitter action produces a minimum of current flow through the local receiver. The means used to lower sound in the local receiver, introduced at the local transmitter, is called the antisidetone feature.

The antisidetone feature is obtained by matching the impedance of the local talking circuit to the impedance of the main talking circuit (including the line loop). Because the line conditions vary with different lengths of line, the impedance of an average line loop is used as a standard, and the impedance of the local circuit is arranged to balance the average line loop. If any line loop is shorter or longer than the average loop, the sidetone will tend to increase.

When transmitting, winding 3-6 is the primary of the autotransformer and winding 1-2 is the secondary. Winding 6-4 is inductively coupled to the transmission circuit, and voltage is induced in winding 6-4 that opposes the change in transmission current. The desired inductive balance is obtained by the impedance of the antisidetone coil so that a minimum of voltage exists across the receiver terminals, resulting in little or no sound in the receiver during transmission.

Receiving Circuit

The receiving circuit also includes two distinct circuits, the main receiving circuit, and the local receiving circuit. The MAIN RECEIVING CIRCUIT consists of line L1, winding 1-2 of the induction coil, the transmitter, and line L2 (fig. 9-6). This circuit is the same as the main talking circuit during transmission, except winding 1-2 now becomes the primary of the autotransformer instead of the secondary. The LOCAL RECEIVING CIRCUIT includes capacitor C2, windings 3-6 and 6-4 of the induction coil, the receiver, and transmitter (fig. 9-6). As previously explained, the antisidetone feature prevents the local transmitter from affecting the receiving circuit.

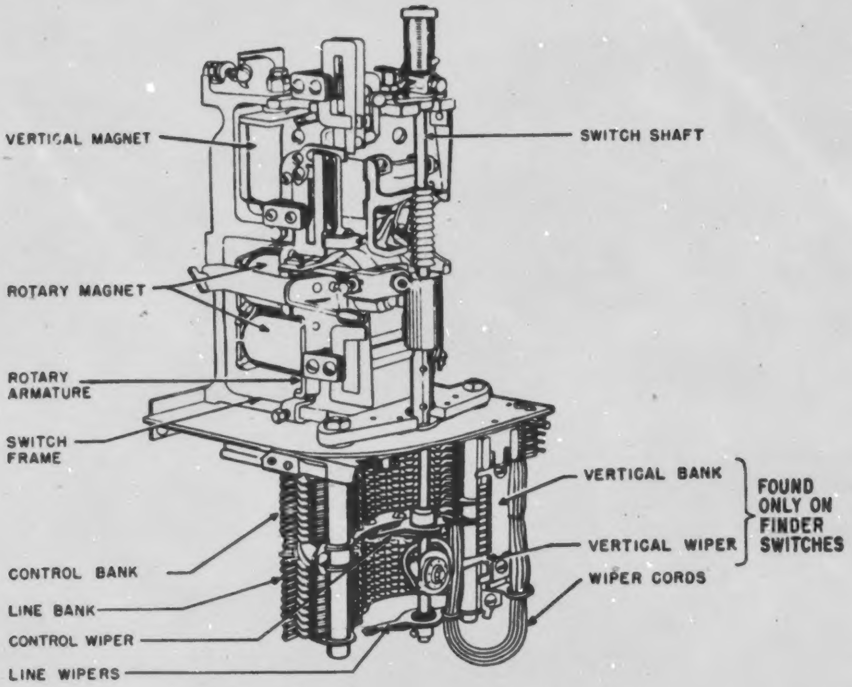
During the reception of speech, the voice currents are received via the main talking circuit which include line L1, winding 1-2 of the induction coil, the transmitter, and line L2. The voice currents flowing in winding 1-2 of the induction coil, considered as the primary of the autotransformer, will induce voltages in the secondary windings 3-6 and 6-4. (Because of the antisidetone feature the local transmitter has no effect on the receiving circuit.) The a-c voltage induced in windings 3-6 and 6-4 causes signal currents to flow through the receiver which (by action of the diaphragm) reproduces the tone and words of the person speaking into the transmitter at the other end of the connection.

AUTOMATIC SWITCHBOARD EQUIPMENT

The automatic switchboard is the switching center of the dial telephone system. Mounted on this switchboard are all telephone switching mechanisms, control circuits, line disconnect keys, part of the testing equipment, and most of the supervisory alarm signals.

These switch mechanisms automatically perform the following functions:

1. Locate a station desiring to make a call.
2. Respond to dial impulses and extend the calling station to the called station.
3. Ring the called station and, if necessary select between the two parties on a party line.
4. Supply various tones, such as dial tone, busy tone, and ring-back tone as required.
5. Provide "hunt-the-not-busy-line" service where required. This is a feature whereby if the lowest numbered of a consecutively numbered group of line stations is called, the switchboard will automatically connect the calling line station to the lowest numbered idle line station of such a group. A busy signal is returned only if all line stations of the group are busy.
6. Provide "executive cut-in" service to line stations as specified. This feature enables such line stations to complete their connection to any line station they may call irrespective of whether that line station is busy.
7. Disconnect the calling and called stations at the completion of the conversation.
8. Perform certain other operations in connection with telephone service.



140.129

Figure 9-8.—Strowger switch.

SWITCHING

Numerous methods of switching, such as "all relay," "rotary," "panel," "crossbar," and "step-by-step" have been devised and are used commercially. The most extensively used switching equipment for shipboard installations is the Strowger automatic type. The switch mechanisms used in this type of equipment operate on a step-by-step basis—that is, the switching functions are accomplished electromagnetically in synchronism with the dial impulses.

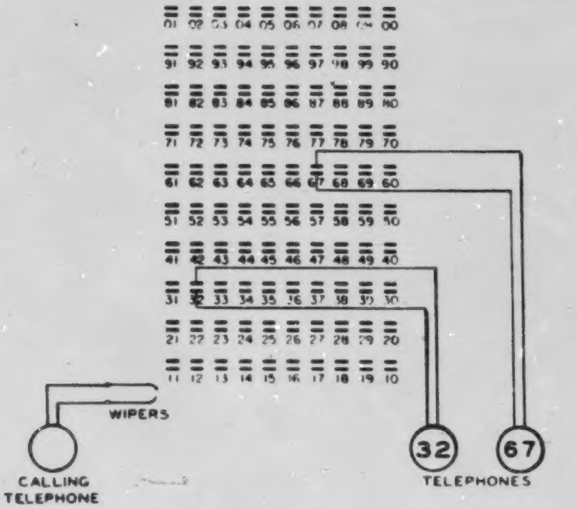
The Strowger switch is an electromechanical device which, switch by switch, extends the connection from the calling to the called telephone. The assembly of electrical contacts, arranged in ten levels, generally ten contacts to a level, is called a bank. The electrical members which make contact with the selected set of contacts in the banks are called wipers. These wipers are connected to the switch shaft.

The switch mechanism elevates the shaft (therefore the wipers) and then rotates the shaft (and wipers). Because of this up-and-around motion, the Strowger switch is often referred to as a two-motion switch.

The Strowger switch is the basic switch of the step-by-step system being used as a linefinder, connector, and selector, in each case employing slightly different electrical and mechanical variations. Figure 9-8 shows the mechanical elements common to all Strowger switches. As one of its variations, the linefinder has an additional set of vertical wipers connecting to a vertical bank.

LINE GROUPING AND NUMBERING

The basic system of grouping provides for a maximum of 100 lines, as shown in figure 9-9. The horizontal dashes represent 100 pairs of metallic contacts. There are 10 horizontal levels and 10 sets of contacts in each level. Thus the tens digit of the called number represents the level whereas the units digit represents the individual pair of contacts in the level.



7.77(27C)

Figure 9-9.—Connector-bank numbering.

Numbers beginning with 1 are in the first, or bottom, level, numbers beginning with 2 are in the second level, and so on. This arrangement causes the digit "0" to be used to represent 10 steps so that the 10th, or top, level is indicated by the symbol for zero. Also, the 10th pair of contacts in each level is indicated by the symbol for zero. Groups of 10 lines are referred to as lines 11-10, 21-20, 31-30, and so forth. The first 10 lines consist of 11-10, and the last 10 consist of 51-50.

Each pair of metallic contacts is connected to a pair of wires that lead to a certain telephone. These contacts are actually contained in a Strowger switch, arranged in the arc of a circle with the vertical rows paralled to the axis of the cylinder. The entire assembly of contacts is called a CONNECTOR BANK.

A pair of metallic wipers mounted on the shaft of the Strowger switch is shown at the lower left-hand corner of the connector bank. These wipers are moved under the control of the dial on the calling telephone. For example, if the calling telephone is used to call telephone No. 32, when digit "3" is dialed the wipers step UP to the third level in the connector bank. When digit "2" is dialed the wipers rotate IN 2 steps on the third level. This action connects the calling telephone with telephone 32. Likewise, to connect the calling telephone with telephone 67, the wipers step UP 6 steps and then rotate IN 7 steps.

BASIC 100-LINE SYSTEM

The system described with reference to figure 9-9 is not practical because only the calling telephone can originate calls. The basic 100-line system is shown in figure 9-10. Each telephone is connected to the wipers of its own connector bank. The wiper of each bank can be stepped up and rotated in, under the control of the dial of the associated telephone. One connector bank with its wipers and the mechanism necessary to step the wipers up and in constitute a CONNECTOR SWITCH. A connector switch is referred to as a NUMERICAL type of Strowger switch because it operates under the control of dial impulses.

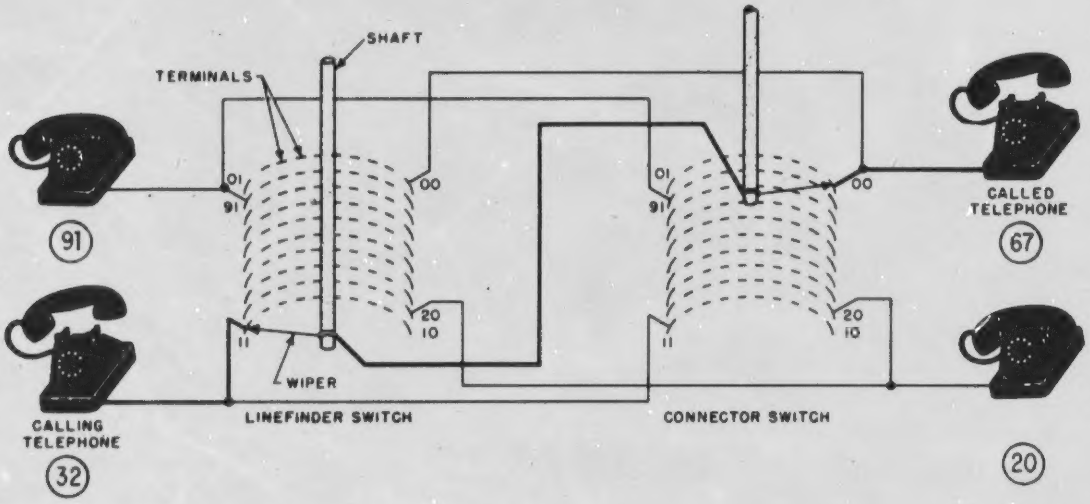
The connector bank described with reference to figure 9-9 has only the 100 pairs of contacts required for the positive and negative lines. In practice, the connector and other switches have one or more banks, with associated wipers, contained in the same switch. However, these banks are for control and special purposes and are not considered now.

For simplicity, only 4 of the 100 telephones with these associated finder-connector links are shown in figure 9-10. Also, only 1 wire from each telephone is indicated, and a black dash represents 1, 2, or as many contacts as are necessary to complete the circuit.

Telephone 32 is connected to the wipers of connector 32. Telephone 32 also has an appearance in the bank of each connector—that is, it is multipled to contact 32 in all of the connector banks. Telephone 67 terminates in wiper connector 67 and is likewise multipled to its associated contact 67 in all of the connector banks. This multiple arrangement of the connector banks permits any telephone to be used to call any other telephone in the system.

LINE FINDING

The 100-line connector system described with reference to figure 9-10 requires an individual connector switch for each line in this system. As the connector is a relatively expensive switch, this system is not economical because the average telephone is used for making calls only a short time each day with the result that the corresponding connector switch would remain idle during the remainder of the time,


SHAFT
TERMINALS
01
91
00
20
10
11
WIPER
01
91
00
20
10
11
CALLED TELEPHONE
67
91
CALLING TELEPHONE
32
20
LINEFINDER SWITCH
CONNECTOR SWITCH

7.78(140B)

Figure 9-10.— Basic 100-line connector system.

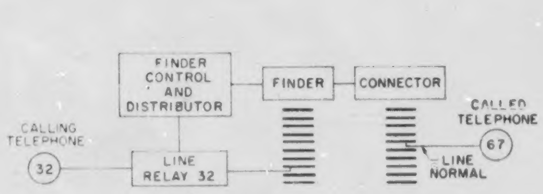
Line finding enables a large group of lines to be served by a smaller number of switches used in common by all lines in the group. The line-finding principle is illustrated by means of the diagram of two 100-point blanks shown in figure 9-10. One is called the FINDER BANK and the other is the previously mentioned CONNECTOR BANK. The finder bank is similar to the connector bank. Although one telephone is shown, actually there are 100 telephones connected to the finder bank. One finder bank with its wipers and the mechanism necessary to step the wipers up and in constitute a FINDER SWITCH. A finder switch is referred to as a NONNUMERICAL type of Strowger switch because its operation is automatic and not under the control of dial impulses.

To call telephone 67 from telephone 32, remove the handset from the cradle at telephone 32. The finder switch (fig. 9-10) automatically steps its wipers up to the third level and rotates in 2 steps, stopping on contact 32. Thus the calling telephone is extended through to the wipers of the connector switch. When the digits "6" and "7" are dialed, the wipers of the connector switch step up to the sixth level and rotate in 7 steps, completing the connection between telephones 32 and 67.

BASIC 100-LINE FINDER-CONNECTOR SYSTEM

The system described with reference to figure 9-10 is equipped with one finder switch and one connector switch. Hence, only one conversation is possible at any one time because each conversation requires one finder and one connector to complete and hold a connection between the calling and called telephones.

The 100-line finder-connector system is shown in figure 9-11. Each finder switch is permanently tied "stem to stern" with a connector switch. In other words, the finder is facing backward ready to find any line that originates a call, whereas the connector is facing forward ready to connect to the dialed line. Such a combination


FINDER CONTROL AND DISTRIBUTOR
FINDER
CONNECTOR
CALLED TELEPHONE
CALLING TELEPHONE
67
32
LINE RELAY 32
LINE NORMAL

7.80(140B)

Figure 9-11.—Complete finder-connector system.

of finder and connector is called a FINDER-CONNECTOR LINK. One finder-connector link is required for each of the conversations that are to be held simultaneously. The links are analagous to the "cord circuits" in a manual telephone system.

Each of the 100 lines is connected to each finder bank. Hence, any idle finder is capable of stepping up and rotating in to locate any one of the 100 lines that originates a call. Also, each of the 100 lines is connected to each connector bank. Hence, under control of dial impulses from the calling telephone the connector tied to the idle finder can step up and rotate in to complete a connection to any one of the 100 telephones. The leads from the connector banks to the 100 telephone lines are called LINE NORMALS.

To call telephone 89 from telephone 32, remove the handset from the cradle at telephone 32. An idle finder, such as finder I, steps up, rotates in, and stops on contact 32. The connection is now extended through to the connector associated with the finder, in this case connector 1, and the dial tone is received by the calling telephone. The DIAL TONE is a signal for the person making the call to dial the number of the called telephone. When digits "8" and "9" are dialed, the wipers of the connector switch step up, rotate in, and stop on contact 89.

The connection is now completed from telephone 32, through finder-connector link 1, and back over the line normal of line 89 to telephone 89. The connector switch now tests telephone 89 and, if it is not in use, ringing current is sent out to operate the ringer at telephone 89. If telephone 89 is found to be in use, a busy signal is returned to the calling telephone.

In the finder-connector system shown in figure 9-11, the finder and connector banks are each represented by 10 horizontal lines. The rectangles at the top of the finder and connector banks represent the switch mechanisms. One line relay is associated with each line whereas one finder control and distributor equipment is common to all lines. Only one finder-connector link is shown. However, there are many such links provided for each 100 lines.

To call telephone 67 from telephone 32, remove the handset from the cradle at telephone 32. Line relay 32 operates and marks the position of line 32 in the finder banks.

When the line relay operates it also sends a START SIGNAL to the finder control and distributor equipment.

The signal causes this equipment to start a preselected idle finder searching for the calling line.

The finder control and distributor equipment at this time automatically preselect the next idle finder to have it ready to search for the next incoming call.

The finder searching for line 32 finds it and extends the connections through to the connector switch.

At this point line 32 is made busy at the connector banks to guard against intrusion from any incoming calls. Also, line relay 32, which is a 2-step relay, now operates the remainder of its contact springs, which cut off its own windings from the line. This action is called CLEARING the line of attachments. The 2-step relays are sometimes called LINE and CUTOFF RELAYS because of this dual function.

The connector switch returns a dial tone to the calling telephone and the call proceeds as previously explained.

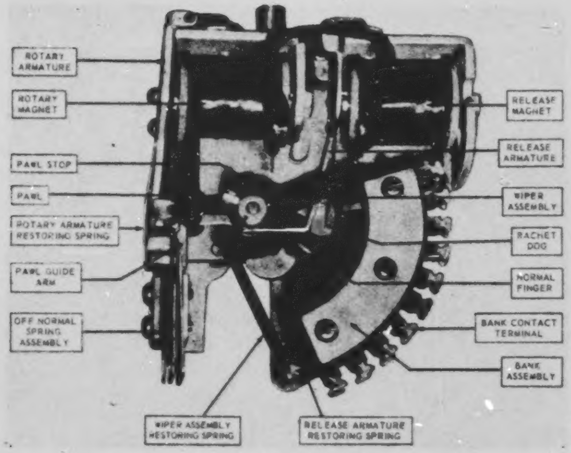
Only one finder control and distributor is shown in figure 9-11. In practice the finder switches are divided into groups A and B, with each group equipped with its own finder control and distributor equipment.

Expanding the 100-line System

The 100-line finder connector system can be expanded to service as many as 200 telephones through the use of a party line system, made possible through the use of an additional switch called a minor switch. This switch has rotary motion only and is therefore referred to as a single-motion switch. As pictured in figure 9-12 the minor switch bank consists of ten sets of contacts over which the wipers may step under control of the dial. This switch, which may be likened to a one-level Strowger switch, is a one-function auxiliary switch used for ringing one or the other of two parties on a party line.

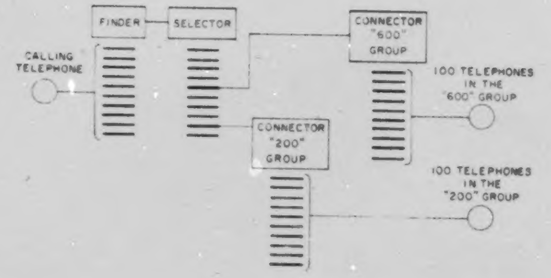
With the minor switch arrangement an additional digit is added to all phone numbers. In this type of equipment telephones having their first digit as 1, 2, 3, 4, 5, 6, 7, 8, or 0 will receive ring current over their positive line while those whose first digit is a 9 will receive ring current over their negative line.

Due to the need of certain lines being used for specific, predesignated purposes, the dial system using a minor switch is restricted to 196 number assignments. These restrictions will be covered in the portion of this chapter dealing with types of calls.


ROTARY ARMATURE
ROTARY MAGNET
PAWL STOP
PAWL
ROTARY ARMATURE RESTORING SPRING
PAWL GUIDE ARM
OFF NORMAL SPRING ASSEMBLY
WIPER ASSEMBLY RESTORING SPRING
RELEASE ARMATURE RESTORING SPRING
RELEASE MAGNET
RELEASE ARMATURE
WIPER ASSEMBLY
RACHET DOG
NORMAL FINGER
BANK CONTACT TERMINAL
BANK ASSEMBLY

140.76

Figure 9-12.—Minor switch.


FINDER
SELECTOR
CALLING TELEPHONE
CONNECTOR "600" GROUP
CONNECTOR "200" GROUP
100 TELEPHONES IN THE "600" GROUP
100 TELEPHONES IN THE "200" GROUP

7.82(27C)

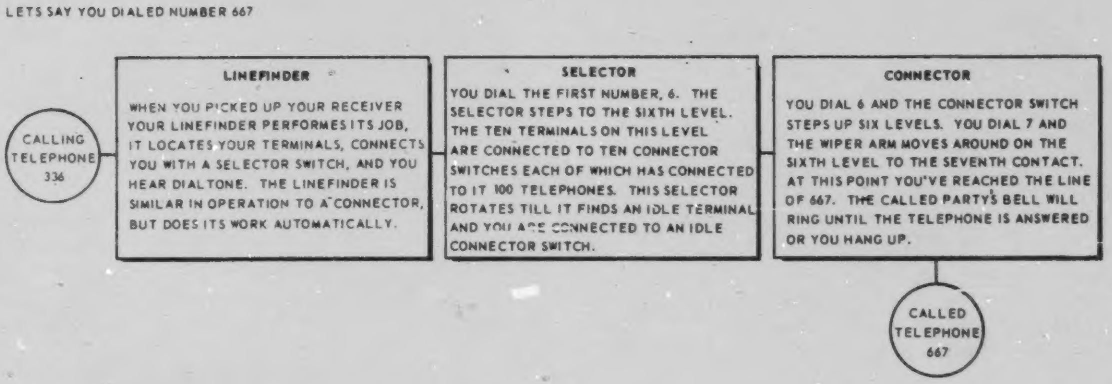
Figure 9-13.—Basic selector system.

BASIC SELECTOR SYSTEM

The system described with reference to figure 9-10 has a capacity of 100 lines. It will serve any number less than 100, such as 50 or 25. The number of lines to be served is wired to only the required finder and connector banks. For systems comprising 200 lines or more a SELECTOR is connected between the finder and connector switches, as shown in figure 9-13. The selector is similar in mechanical construction to both the finder and connector. It has the same bank, wipers, and 2-motion mechanism.

The selector faces the called line the same as does the connector. The function of the selector is to select the "hundreds" group of lines. From then on, a connector selects both the "tens" groups of lines and the "units" line in that group. Note that the lines are divided into groups of 100. Two such groups are shown, the "200" group with 100 lines and the "600" group with 100 lines. Each group has a corresponding group of connectors having their banks multipled together.

In figure 9-14, a call through a 200-line capacity system is traced from the calling telephone to the called telephone. Note that


CALLING TELEPHONE 336
CALLED TELEPHONE 667

LETS SAY YOU DIALED NUMBER 667

LINEFINDER

WHEN YOU PICKED UP YOUR RECEIVER YOUR LINEFINDER PERFORMES ITS JOB, IT LOCATES YOUR TERMINALS, CONNECTS YOU WITH A SELECTOR SWITCH, AND YOU HEAR DIALTONE. THE LINEFINDER IS SIMILAR IN OPERATION TO A CONNECTOR, BUT DOES ITS WORK AUTOMATICALLY.

SELECTOR

YOU DIAL THE FIRST NUMBER, 6. THE SELECTOR STEPS TO THE SIXTH LEVEL. THE TEN TERMINALS ON THIS LEVEL ARE CONNECTED TO TEN CONNECTOR SWITCHES EACH OF WHICH HAS CONNECTED TO IT 100 TELEPHONES. THIS SELECTOR ROTATES TILL IT FINDS AN IDLE TERMINAL AND YOU ARE CONNECTED TO AN IDLE CONNECTOR SWITCH.

CONNECTOR

YOU DIAL 6 AND THE CONNECTOR SWITCH STEPS UP SIX LEVELS. YOU DIAL 7 AND THE WIPER ARM MOVES AROUND ON THE SIXTH LEVEL TO THE SEVENTH CONTACT. AT THIS POINT YOU'VE REACHED THE LINE OF 667. THE CALLED PARTY'S BELL WILL RING UNTIL THE TELEPHONE IS ANSWERED OR YOU HANG UP.

140.130

Figure 9-14.—A call through a 200 line system.

the finder switch is tied "stem to stern" with a selector switch, instead of being tied to a connector switch as in the 100-line capacity system. However, one finder-selector link is required for each conversation that is to be held simultaneously. The connector switch always operates last and selects the "tens" group of lines and the "units" line within the group.

To call telephone 673, remove the handset from the cradle at the calling telephone. An idle finder searches and extends the calling line to the selector switch associated with that particular finder. The selector returns a dial tone to the calling telephone. When the "hundreds" digit, "6," is dialed, the selector wipers step up to the sixth level, and automatically rotate in on that level in search of a contact that is attached to an idle connector switch. The leads to the connectors are called TRUNKS and the automatic selection of an idle trunk is called TRUNK HUNTING.

A selector switch is capable of searching over the 10 contacts, on the dialed level, more quickly than a calling person can dial the next digit. If all 10 contacts test busy, the selector switch returns a busy signal to the calling person.

If the selector finds an idle trunk, the call is extended through to a connector. When digits "7" and "3" are dialed, the connector steps up 7 level and rotates in 3 steps to complete the call. Because the dialed digits extend the call step by step, the Strowger automatic telephone equipment is referred to as a STEP-BY-STEP system.

TELEPHONE CONNECTIONS

All telephones are provided with screw type terminals and therefore soldering is not necessary in order to connect or replace a telephone. All conductors are color-coded and the correct termination for each conductor is shown in terms of the color code on the circuit lable inside the telephone base or on the wiring diagram. When changing or replacing any wiring in or to a telephone, check the new connections against the circuit label inside the telephone or the applicable wiring diagram.

Line Stations

The several types of telephones can be connected for one-party service or two-party service. For a ONE-PARTY line two conductors are required to extend the connection between the telephone instrument and the automatic switchboard. These are the line conductors designated L1 and L2 on the circuit labels and telephone wiring diagrams. On a one-party line the ringer is across the line and the line conductors are also the conductors for the ringer circuit. This arrangement is called METALLIC RING.

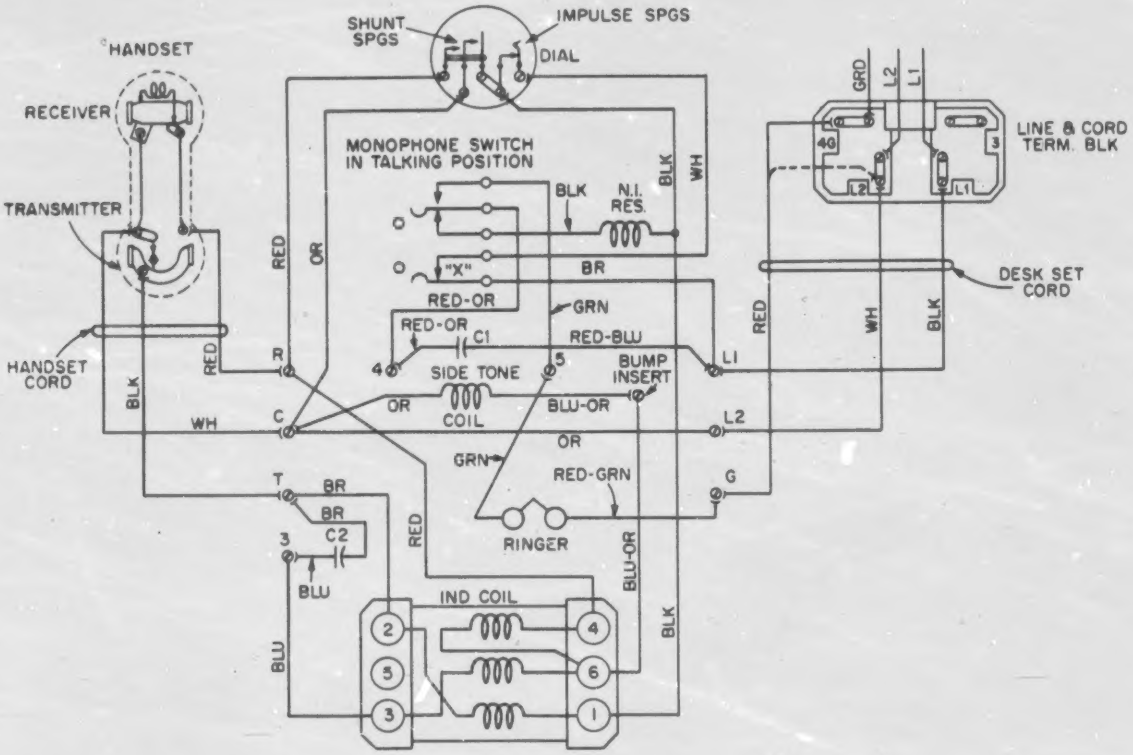
For a TWO-PARTY line three conductors are required to extend the connection between the telephone instrument and the automatic switchboard. The two line conductors are designated L1 and L2 and the third conductor, which is connected to a ground (positive battery) common to all ringer circuits in the shipboard dial telephone system, is designated G.

When two telephones are connected electrically to the same line circuit, their ringers cannot be connected across the line unless one telephone is to be an extension telephone. When two-party service with individual ringing is desired, the two telephones must be arranged so that ringing current will operate only the ringer of the called telephone. Thus, to obtain separate ringers circuits for the two telephones, the ringer of one telephone is connected between the positive line conductor L1, and ground (positive ring), whereas, the ringer of the other telephone is connected between the negative line conductor L2, and ground (negative ring).

Therefore, on party lines it is necessary that the ringers be connected to the proper side of the line. The telephone system is arranged so that the side of the telephone line on which ringing current is applied is determined by the telephone number.

Type A Telephone

The type A telephone (fig. 9-15) is equipped with a terminal subassembly inside the base and a line-and-cord terminal block on the end of the desk set cord. The line wires L1 and L2 from the automatic switchboard terminate at the line-and-cord terminal block and the wiring of the telephone instrument terminates at the instrument terminal subassembly. The desk set cord extends the connection between the telephone wiring at the instrument subassembly and the line wiring at the line-and-cord terminal block. The type A telephone may be connected for ONE-PARTY line service (metallic ring) by connecting at the line-and-cord terminal block the red-coded and white-coded wires to terminal L2, and the black-coded wire to terminal L1, (fig. 9-16A). Proper operation of the ringer is determined by dialing, from a nearby telephone, the number assigned to the telephone just connected. The ringer should ring.


SHUNT SPGS
IMPULSE SPGS
DIAL
HANDSET
RECEIVER
TRANSMITTER
MONOPHONE SWITCH IN TALKING POSITION
BLK
N.I. RES.
BLK
WH
"X"
BR
RED
OR
RED-OR
RED-OR
GRN
C1
RED-BLU
HANDSET CORD
RED
R
4
5
SIDE TONE COIL
BUMP INSERT
L1
OR
BLU-OR
BLK
WH
C
L2
OR
GRN
RED-GRN
T
BR
G
BR
C2
3
RED
RINGER
BLU
BLU-OR
IND COIL
BLU
BLK
2
4
5
6
3
1
GRD
L2
L1
4G
3
L2
L1
LINE & CORD TERM. BLK
DESK SET CORD
RED
WH
BLK

7.89

Figure 9-15.—Type A telephone wiring diagram.

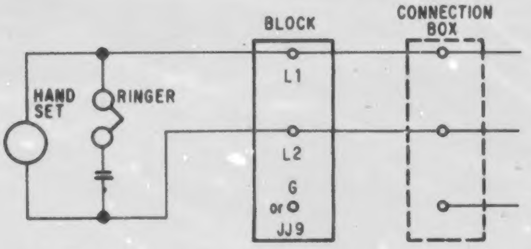
The type A telephone (fig. 9-15) is connected for TWO-PARTY line service (ground ring) by connecting, at the line-and-cord terminal the black-coded wire to terminal L1, the white-coded wire to terminal L2, and the red-coded ground wire to terminal 4G. One other connection is necessary to complete the job, at the terminal block in the telephone connect the red-green-coded wire as shown in figure 9-16B for either positive party ring or negative party ring. From a nearby telephone, dial the number assigned to the telephone just connected. If the ringer does not ring, reverse the line wire connections at the line-and-cord terminal block. Repeat the test.

At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, remove the base plate and reverse the ringer terminals 5 and G. Repeat the test. If the ringer still taps, increase the tension of the biasing springs. The biasing springs should be as nearly parallel as possible to the ringer coil cores. To increase the tension in the biasing springs bend the lower mounting lug (not shown) downward with a pair of pliers. Repeat the test.

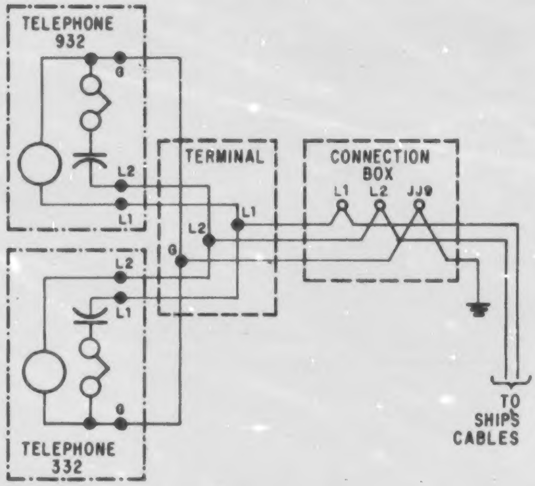
Type F Telephone

The type F telephone (fig. 9-17) is equipped with a terminal subassembly mounted on the bottom cover plate inside the telephone housing. The ship's cable consisting of line wires J95 and JJ95, (connector terminals 95 of line 95 are used here as an example) battery-connected wire JJ9, and ground-connected wire J9, enters through a terminal tube at the bottom of the housing.

The type F telephone is connected for ONE-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal L2, the line wires J95 and JJ95 to terminal L1 and L2, respectively, the ground-connected wire J9 to terminal G, and the battery-connected wire JJ9 to terminal B. Remove the


BLOCK
CONNECTION BOX
HAND SET
RINGER
L1
L2
G or JJ9

Ⓐ METALLIC RING (One Party Service)

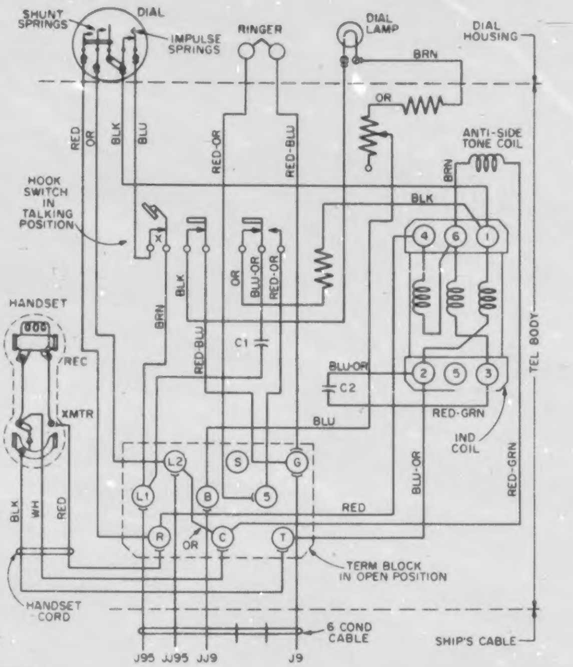

TELEPHONE 932
G
L2
L1
TERMINAL
L2
L1
G
CONNECTION BOX
L1 L2 JJ9
TELEPHONE 332
TO SHIPS CABLES

Ⓑ TWO-PARTY LINE CONNECTIONS

140.131
Figure 9-16.—One-party and two-party line connections.

handset from the hook switch. The dial lamp should light and a dial tone should be heard. From a nearby telephone, dial the number assigned to the telephone just connected. The ringer should ring.

The type F telephone (fig. 9-17) is connected for TWO-PARTY line service by connecting at the terminal subassembly, the red-blue ringer wire to terminal G, and the ship's cable wires J95, JJ95, and J9, and JJ9 to terminals L1, L2, G, and B, respectively. From a nearby telephone, dial the number assigned to the telephone just connected. If the ringer does not ring, reverse the line-wire connections at terminals L1 and L2. Repeat the test.

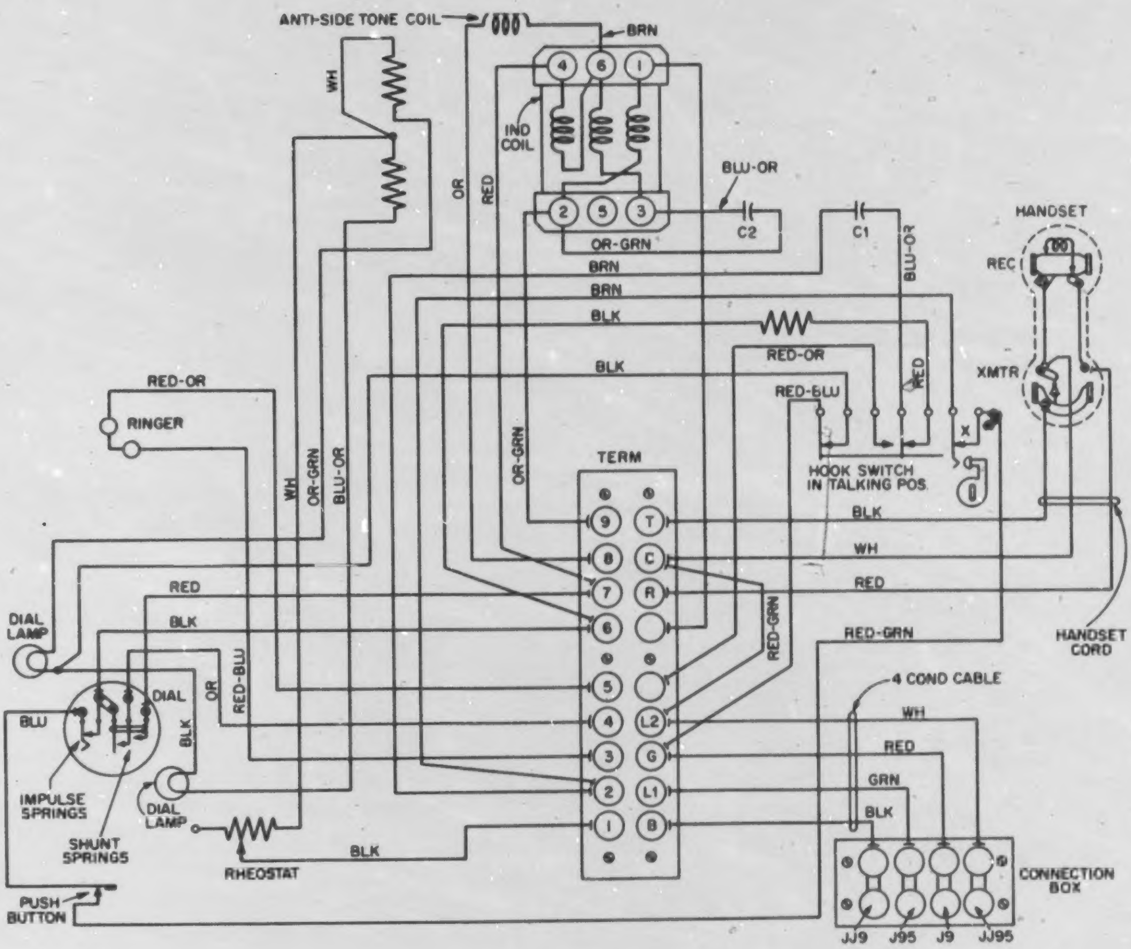

SHUNT SPRINGS
DIAL
IMPULSE SPRINGS
RINGER
DIAL LAMP
DIAL HOUSING
BRN
OR
ANTI-SIDE TONE COIL
RED
OR
BLK
BLU
RED-OR
RED-BLU
HOOK SWITCH IN TALKING POSITION
BLK
4 6 1
HANDSET
REC
XMTR
BRN
BLK
OR
BLU-OR
RED-OR
RED-BLU
C1
BLU-OR
C2
2 5 3
TEL BODY
RED-GRN
IND COIL
BLU
L2
S
G
L1
B
5
BLU-OR
RED-GRN
RED
BLK
WH
RED
R
OR
C
T
TERM BLOCK IN OPEN POSITION
HANDSET CORD
6 COND CABLE
SHIP'S CABLE
J95 JJ95 JJ9
J9

7.90
Figure 9-17.—Type F telephone wiring diagram.

At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, reverse the red-blue and the red-orange ringer connections at terminals 5 and G. Repeat the test. If the ringer still taps, increase the tension of the biasing spring (not shown) by bending the end mounting lug with a pair of pliers. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard. Replace the handset.

Type C Telephone

The type C telephone (fig. 9-18) is equipped with a terminal subassembly and a terminal block inside the housing. This ship's cable, consisting of wires J95, JJ95, J9, and JJ9 are connected to L1, L2, G, and B, respectively, on the terminal block. The wires L1, L2, G, and B on the terminal block are connected to corresponding terminals on the terminal subassembly.


ANTI-SIDE TONE COIL
BRN
WH
IND COIL
OR
RED
BLU-OR
C2
C1
HANDSET
REC
OR-GRN
BRN
BRN
BLK
RED-OR
BLK
XMTR
RED-OR
RED-BLU
RED
RINGER
X
TERM
HOOK SWITCH IN TALKING POS.
WH
OR-GRN
BLU-OR
OR-GRN
9
T
BLK
8
C
WH
7
R
RED
RED
DIAL LAMP
BLK
6
RED-GRN
RED-GRN
HANDSET CORD
5
4 COND CABLE
DIAL
OR
RED-BLU
BLU
BLK
4
L2
WH
3
G
RED
IMPULSE SPRINGS
2
L1
GRN
DIAL LAMP
1
B
BLK
SHUNT SPRINGS
BLK
RHEOSTAT
CONNECTION BOX
PUSH BUTTON
JJ9
J95
J9
JJ95

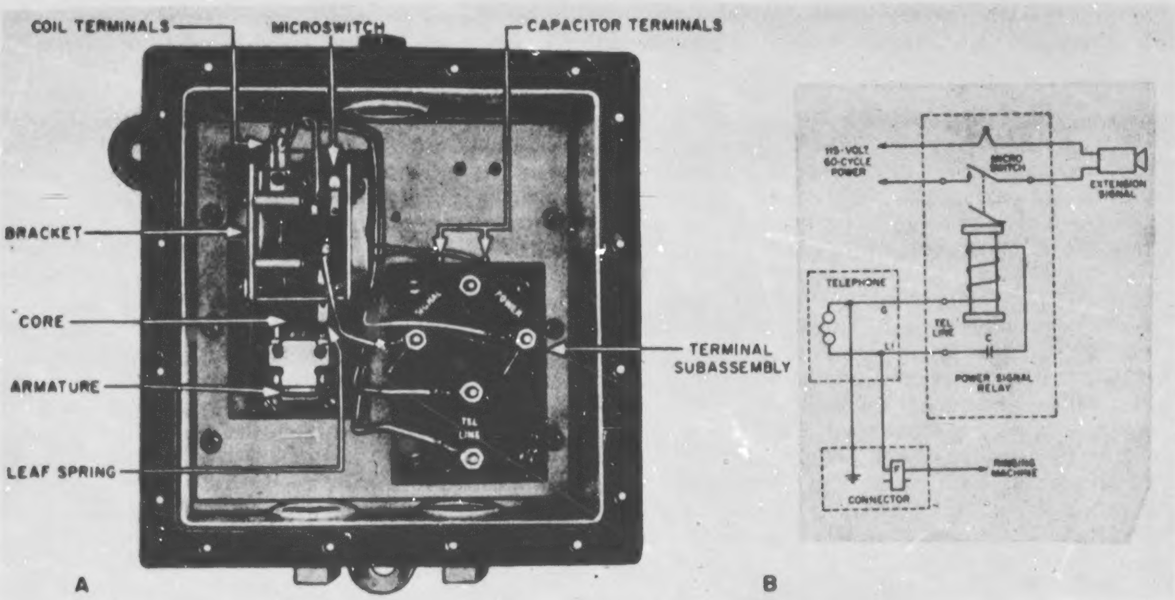
7.91

Figure 9-18.--Type C telephone wiring diagram.

The type C telephone is connected for ONE-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal 4 (L2). From a nearby telephone, dial the number assigned to the telephone just connected. The ringer should ring. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard.

The type C telephone (fig. 9-18) is connected for TWO-PARTY line service by connecting, at the terminal subassembly, the red-blue ringer wire to terminal 3 (G). From a nearby telephone, dial the number assigned to the telephone just connected. If the telephone ringer does not ring, reverse the line-wire connections at terminals L1 and L2. Repeat the test.

At the other telephone on the line, dial any telephone number. If the ringer taps at the telephone just connected, reverse the ringer connections at terminals 3 and 5 on the terminal subassembly. Repeat the test. If the ringer still taps, increase the tension of the biasing spring as previously explained. Remove the handset from the hook switch. The dial lamp should light and dial tone should be heard.


COIL TERMINALS
MICROSWITCH
CAPACITOR TERMINALS
BRACKET
CORE
ARMATURE
LEAF SPRING
SIGNAL
POWER
TEL LINE
TERMINAL SUBASSEMBLY
A
115-VOLT 60-CYCLE POWER
MICRO SWITCH
EXTENSION SIGNAL
TELEPHONE
G
L1
TEL LINE
C
POWER SIGNAL RELAY
F
RINGING MACHINE
CONNECTOR
B

7.92(140A)

Figure 9-19.—Power signal relay.

POWER SIGNAL RELAY

As previously stated, when a telephone is installed in a noisy location, an extension signal may be connected through a power signal relay to the telephone line. The extension signal used with the dial telephone system is a 115-volt 60-hertz motor-operated horn.

The power signal relay (fig. 9-19) includes: (1) coil subassembly, (2) core subassembly, (3) armature, (4) microswitch, and (5) terminal subassembly enclosed in a steel case.

The COIL SUBASSEMBLY consists of a bakelite frame on which is wound a coil of wire. The CORE SUBASSEMBLY consists of a number of U-shaped laminations riveted together. Two brass brackets are riveted to one leg of the core for mounting the armature subassembly and the relay terminals. The coil subassembly is attached to the other leg of the core.

The ARMATURE completes a magnetic path between the two poles of the coil subassembly and actuates the nap-action microswitch. It is provided with a brass residual pin to maintain a small space between the armature and core to prevent sticking.

The MICROSWITCH is provided with large contact surfaces so that large currents can be controlled with relatively small movements of the armature.

The TERMINAL SUBASSEMBLY is provided with terminals for making the connections to the a-c power source, the extension signal, and the telephone line.

The telephone ringer and the power signal relay are connected in parallel to the line of the telephone. The power signal relay has a pair of microswitch contacts, one of which is connected to one side of the extension signal and the other to the a-c power supply. The other side of the extension signal is connected permanently to the a-c power supply.

When the ringing current is applied to the line of the telephone through the winding of the connector relay F, the current energizes both the ringer at the telephone and the coil of the power signal relay. The coil of the power signal relay, when energized, actuates the relay armature to close the microswitch contacts. The microswitch contacts, when closed, complete the a-c power circuit to sound the extension signal. As soon as the handset is removed from the hook switch, the ringing current is removed from the line, the power signal relay restores, and the circuit to the extension signal is opened at the microswitch contacts.

Type F Telephone

When a type F telephone is installed in a noisy location, an extension signal is connected through a power signal relay to the telephone line. When the telephone is arranged for extension signal ringing, it is recommended that the instrument be connected for ground ring irrespective of whether it is a one-party or two-party line, in order to eliminate any possibility of the extension signal being actuated during dialing.

At the terminal subassembly (fig. 9-17), connect the red-blue ringer wire to terminal G, the ship's cable wires J95, JJ95, J9, and JJ9 to terminals L1, L2, G, and B, respectively, and the two line wires from the power signal relay to terminals L1 and G. From a nearby telephone, dial the number assigned to the telephone just connected. If the extension signal does not operate, move the power signal relay lead from the L1 to the L2 terminal. Repeat the test.

Type C Telephone

When a type C telephone is installed in a noisy location, it is arranged for extension signal ringing and connected for ground ring irrespective of whether it is a one-party or two-party line.

At the terminal block (fig. 9-18) the ship's cable wires J95, JJ95, J9, and JJ9 are connected to terminals L1, L2, G, and B, respectively, and the two line wires from the power signal relay to terminals L1 and G. At the terminal subassembly, connect the red-blue ringer wire to terminal 3 (G) and the wires from the terminal block to the corresponding terminals, L1, L2, G, and B. From a nearby telephone, dial the number assigned to the telephone just connected. If the extension signal does not operate, move the power signal relay lead from terminal L1 to terminal L2. Repeat the test.

TYPES OF CALLS

The shipboard dial telephone system is designed to permit a wide variety of telephone calls to meet a variety of needs. These calls are summarized below.

Regular local service is the routine call wherein the caller dials the desired number and receives either a ring-back or a busy tone in his receiver. In the event the called station is manned, the call should, if the phone is not in use, be completed. In the event a busy tone is received it is necessary that the calling phone redial the number in order to again attempt the call.

Executive service is that additional feature by which a priority telephone will cut in on a connection which has already been made to the number which he wishes to reach. An executive phone always reaches the party called, even when the line is busy.

Emergency service is a specifically designed feature by which any number dialing digits 211 reaches the station at which the Officer of the Deck has posted his watch, be it the Quarterdeck or the Pilot House. The call is also extended through regardless of whether the line is open or busy. A switch controlling the recipient phone (Quarterdeck or Pilot House) is located on the telephone switchboard.

Ship to Shore Call is a call connected manually through the manual switchboard. To complete this call (possible only when in port and connected) the caller would dial the manual switchboard and the ship's operator would then extend the call through to the shore facility.

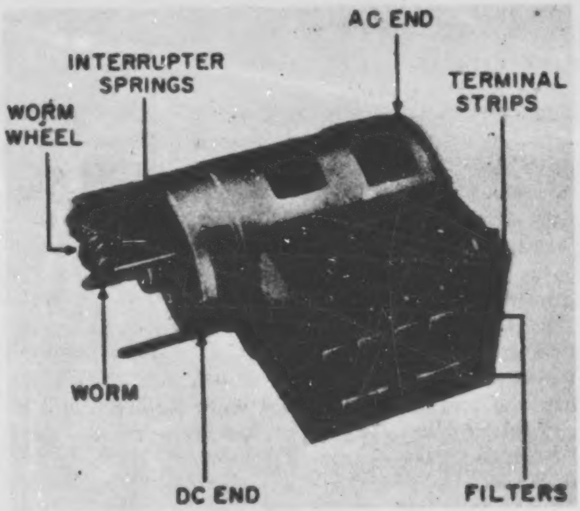
Shore to Ship Call is also a feature conducted through the manual switchboard. Here in again the ship's operator completes the call through the manual facilities available to him at his station. On most installations lines 37, 38, 39, and 30 are reserved for the manual switchboard.

Test Call is a maintenance number, usually line 29, used in troubleshooting the automatic equipment.

An additional feature employed in cases where a series of numbers serve the same space is "hunt the not-busy feature." In this type of arrangement, as in the case of the manual switchboard, assuming that line 37 was in use and a second caller dialed the manual switchboard number 37; the call would be shifted automatically through to line 38. This "hunt" feature continues until it receives busy from the last in a series of so connected lines.

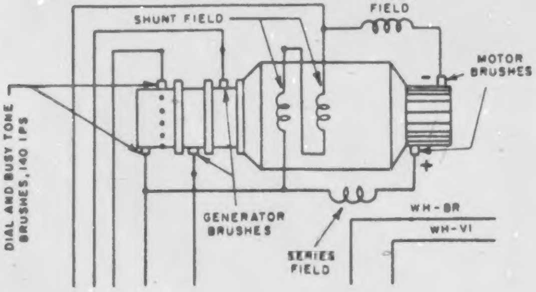
RINGING MACHINES

Ringing equipment consists of two ringing machines, a ringing transformer, test and transfer keys, and associated circuitry. In order to ensure continuous service, two ringing machines are used; one in operation, one in standby. The operating machine provides the ring, busy, dial, and ringback tones to the entire system.

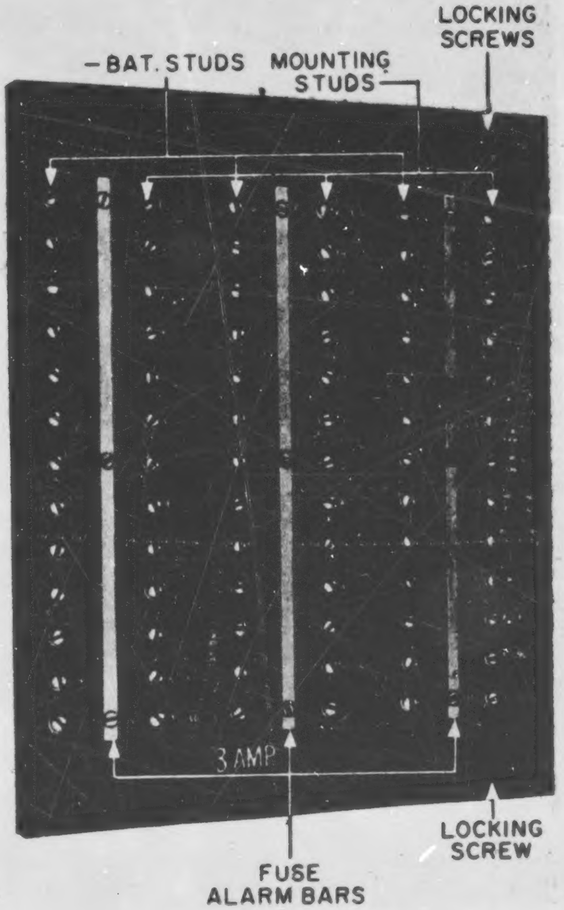

AC END
INTERRUPTER SPRINGS
TERMINAL STRIPS
WORM WHEEL
WORM
DC END
FILTERS

140.82
Figure 9-20.—Ringing machine.

The machine (fig. 9-20) is a rotary converter used to change the d-c of the power section into low voltage a-c and to interrupt d-c for use as the varying tones in the system. The d-c end of the unit is a compound motor. The a-c end of the unit (fig. 7-21) is composed of a four-ring collector consisting of three plain rings and one segment type ring. The ring brushes ride on the first two (plain) collector rings and extend 20-hertz a-c to the ringing transformer. The dial and busy tone brushes bear on the third plain collector and the remaining segment-type ring. These latter two brushes extend an interrupted d-c signal to the system. The dial tone is d-c interrupted 140 times per second. The busy tone is the same tone further interrupted 120 times per minute.


SERIES FIELD
SHUNT FIELD
MOTOR BRUSHES
DIAL AND BUSY TONE BRUSHES, 140 IPS
-
+
GENERATOR BRUSHES
SERIES FIELD
WH-BR
WH-VI

140.83
Figure 9-21.—Ringing machine, partial schematic.

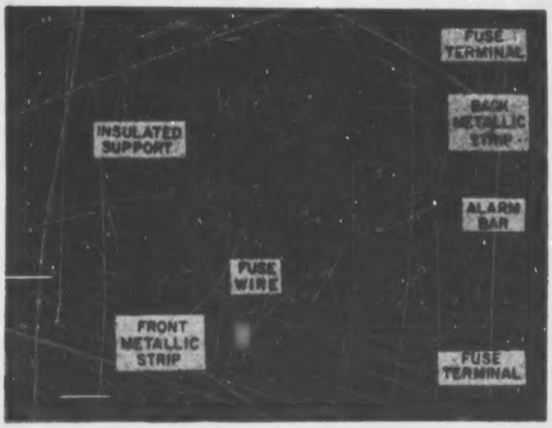

LOCKING SCREWS
-BAT. STUDS
MOUNTING STUDS
3 AMP
LOCKING SCREW
FUSE ALARM BARS

140.84
Figure 9-22.—Fuse panel.

Mounted on the d-c end of the unit is an extension which houses a worm, worm wheel, and cross shaft as well as five sets of interrupter contacts (not shown). This unit regulates the duration of all extended signals.

FUSE PANEL

The fuse panel (fig. 9-22) contains all of the telephone fuses required for the protection of the



140.85
Figure 9-23. — Telephone grasshopper fuse.

switchboard equipment. These are three-ampere alarm-type indicating fuses.

The telephone (grasshopper) fuse is illustrated in figure 9-23. This fuse consists of an insulated support provided with a terminal at each end that is connected across the fuse block on the fuse panel. Metallic strips located on the front and back of this insulated support extend from each fuse terminal about half the length of the support. The free ends of these metallic strips are tied together by fuse wire, thereby placing these strips under slight spring tension. When the fuse blows, the back metallic strip springs backward to make contact with the alarm bar, thereby completing an alarm circuit. The front metallic strip springs forward to indicate the blown fuse.

LINE DISCONNECT KEY PANEL

The line disconnect key panel (fig. 9-24) mounted on the front of the finder board is equipped with 100 keys (one for each line connected to the switchboard). Thus, any line can be disconnected from the switchboard for testing purposes, isolating a faulty line, or cutting out nonessential lines when required. Each line disconnect key has the same number as its associated line. When the key is in the normal position, the telephone line is connected to the associated line relay in the automatic switchboard. When the line disconnect key is operated (pulled out) the connection is opened between the telephone line and the associated line relay.

The line disconnect key can be locked in the OPEN position by inserting a cotter pin in the hole provided in the key shaft. This locking arrangement can be used to prevent ring-back tone from being returned to the calling station when the line disconnect key is associated with an unassigned line.

ALARM SYSTEM

The dial telephone alarm system is an arrangement of signal equipment that gives an alarm if a nonstandard condition exists in the telephone system. The alarm consists of both an audible and a visual signal to indicate the nature and general location of the trouble. The 100-line system will be discussed.

The audible signal is a buzzer or bell that is common to all alarms; whereas, the visual signal is a lamp that is associated with a particular type of alarm. When the common alarm buzzer sounds, one or more alarm lamps will be lighted to indicate the nature of the trouble.

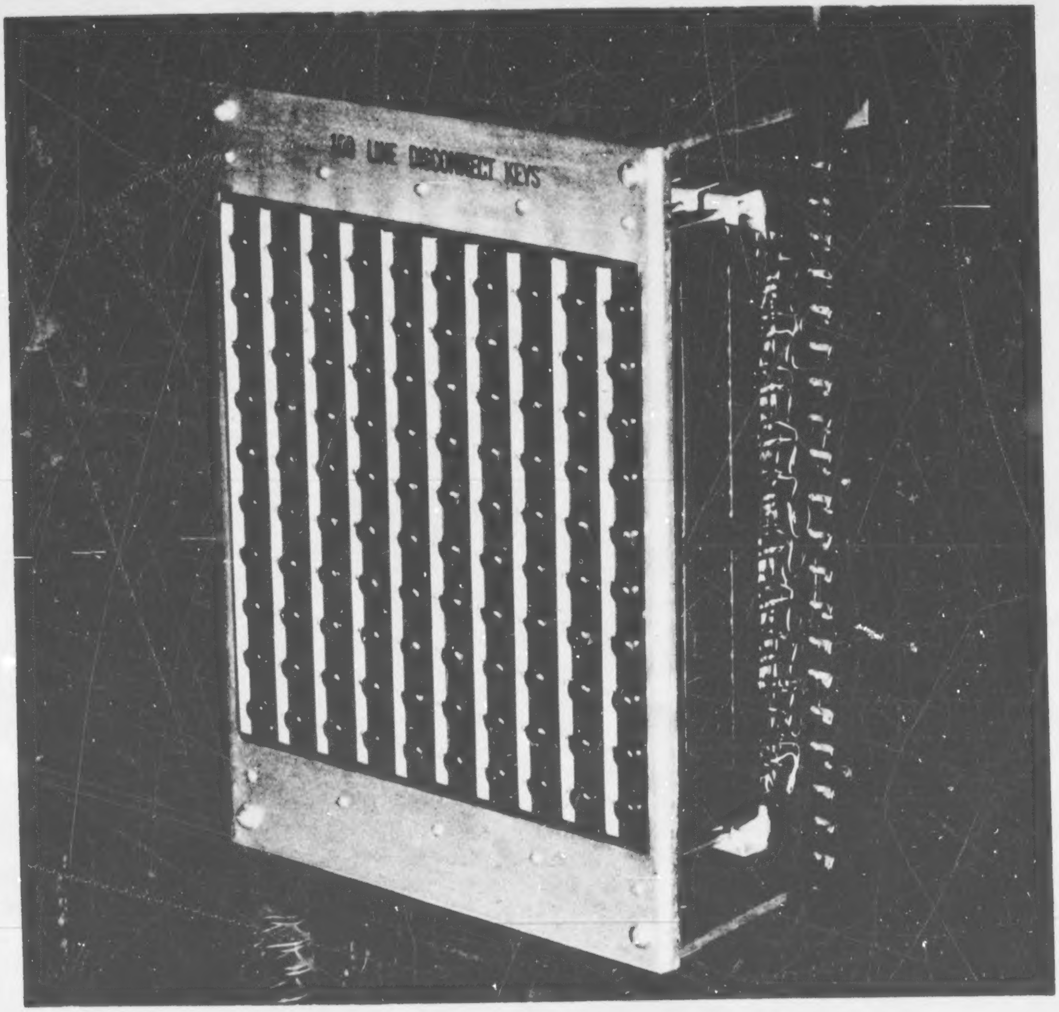
Nonstandard conditions cause either immediate or delayed alarms. For example, an immediate alarm is given when any fuse blows; whereas, a delayed alarm is given when a finder or connector fails to release after the normal releasing time of the switch has elapsed. Predetermined delay intervals are automatically provided by means of the timer relays for each type of alarm that requires a delay.

Lamp and Key Panel

The lamp and key panel (fig. 9-25) mounted on the front of the finder board contains all the alarm lamps for the dial telephone system. The alarm lamps are the (1) power fail, (2) power fuse, (3) motor-generator fail, (4) attendant's cabinet fuse, (5) switchboard fuse, (6) connector release, (7) finder release, (8) finder blocked, A and B, (9) connector permanent, and (10) ringing machine fail, 1 and 2, alarms.

In addition to the alarm lamps, various switches (keys) are mounted on the lamp and fuse panel. These switches are the (1) finder reset, A and B, (2) finder blocked, A and B (3) permanent reset, and (4) shore-line control switches.

Power Fail Alarm. — The power fail alarm lamp (red) will light, and the common alarm buzzer will sound if the switchboard BATTERY VOLTS (maintained by the motor-generator and storage battery in parallel) fall below a predetermined value, or if the power supply fuse



27.208

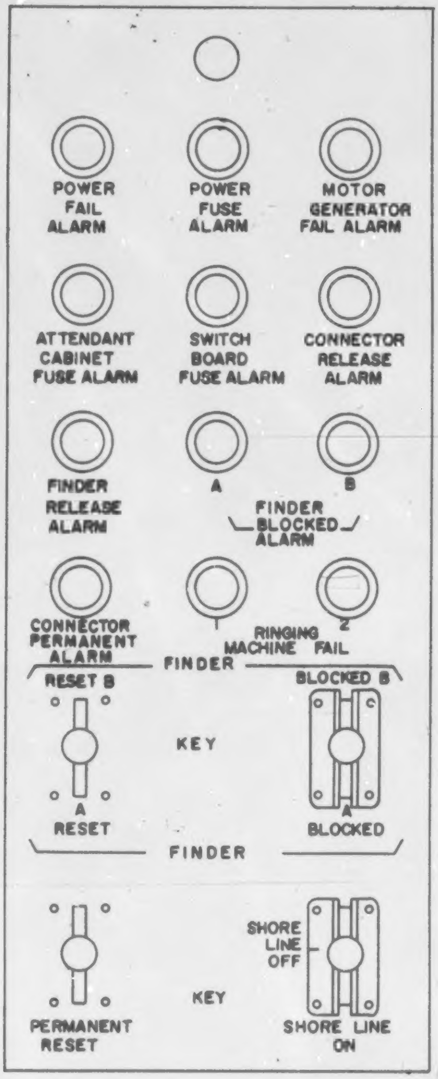
Figure 9-24.—Line disconnect key panel.

blows. This alarm is not provided with a delay interval. All alarms that light the POWER FAIL ALARM lamp should receive immediate attention because when this lamp is lighted the switchboard is completely out of service.

Power Fuse Alarm.—The power fuse alarm lamp (red) will light, and the common alarm buzzer will sound if one or more of the fuses mounted on the power panel (except the voltmeter fuse) should blow. This alarm is not provided with a delay interval.

Motor-Generator Fail Alarm.—The motor-generator fail alarm lamp (red) will light because of (1) failure of the ship's 120-volt power supply, (2) operation of the controller overload contacts (or blown controller fuse), or (3) failure of the generator to cut in after the motor-generator has started. This alarm is so designed that is action is delayed from 15 to 45 seconds.

The POWER FAIL, POWER FUSE, and MOTOR-GENERATOR FAIL alarms are SUPERVISORY alarm lamps provided for the power


POWER FAIL ALARM
POWER FUSE ALARM
MOTOR GENERATOR FAIL ALARM
ATTENDANT CABINET FUSE ALARM
SWITCH BOARD FUSE ALARM
CONNECTOR RELEASE ALARM
FINDER RELEASE ALARM
A
B
FINDER BLOCKED ALARM
CONNECTOR PERMANENT ALARM
1
2
RINGING MACHINE FAIL
FINDER
RESET B
BLOCKED B
KEY
A RESET
A BLOCKED
FINDER
SHORE LINE OFF
KEY
PERMANENT RESET
SHORE LINE ON

140.86

Figure 9-25. — Lamp and key panel.

equipment. The power panel and motor-generator are discussed with the power equipment in a separate chapter.

Attendant's Cabinet Fuse Alarm. — The attendant's cabinet fuse alarm lamp (red) will light, and the common alarm buzzer will sound if a fuse associated with the attendant's cabinet should blow. This alarm is not provided with a delay interval.

Switchboard Fuse Alarm. — The switchboard fuse alarm lamp (red) on the lamp and key panel will light, and the common alarm buzzer will sound if any fuse mounted on the fuse panel should blow. This alarm is not provided with a delay interval.

Connector and Finder Release Alarms. — The connector release alarm lamp (green) or the finder release alarm lamp (green will light, and the common alarm buzzer will sound if a connector or finder switch fails to release when the associated magnet circuit is closed. Each of these alarms is so designed that its action is delayed from 15 to 45 seconds.

The faulty finder or connector switch is located by plugging the hand test telephone (with button C depressed) in the test jack of each switch that is off-normal (if the switch is a finder, note the number and plug the hand test telephone in the correspondingly numbered connector). The hand test telephone is described later in this chapter with the testing equipment. If no conversation is heard, release button C and challenge. If no answer is received, release the switch that is off-normal by manually operating the release magnet. If this action does not extinguish the release alarm lamp, another switch is at fault.

If the cause of the release failure cannot be corrected immediately, make the defective switch busy by operating the BUSY KEY on the connector switch (fig. 9-8). This key makes busy both the connector and the correspondingly numbered finder. In other words, the busy key makes busy the finder-connector link. This action is necessary to prevent seizure of the link for another call until the defective switch is repaired or replaced by a new switch.

Finder Blocked Alarm. — The finder blocked alarm lamp (red) will light, and the common alarm buzzer will sound if the finder allotted to a call fails to function, or fails to complete its function. Group A finders and group B finders are each equipped with an alarm lamp. This alarm is so designed that its action is delayed from 5 to 10 seconds.

If the blocked finder is in the A group of finder, the call at hand, and all subsequent calls, are transferred to the B group of finders. However, if a blocked-call condition or an all-finders-busy condition now appears in the B group, all calls will be transferred back to the A group, which will have stepped on to another finder. These transfers can continue back and forth indefinitely.

For example, if the A finder blocked alarm lamp is lighted, the defective finder can be determined by the following procedures:

1. Operate momentarily the FINDER RESET key to position A.
2. Operate the FINDER TEST key, mounted on the rear of the finder board, to position A.
3. Hold the FINDER TEST key operated to cause the A finders to step UP and IN, and release one after the other. This action will continue until the blocked finder is reached, at which time the B finder will start stepping. The blocked finder is the one located immediately after the last finder that functions properly in the A group. A finder that is properly UP and IN on a call should not be considered when determining the blocked finder. When the defective finder has been located, operate the busy key on the correspondingly numbered connector to "busy out" the finder-connector link until the defective finder can be repaired or replaced by a new switch.
4. Operate momentarily the FINDER RESET key to position A to again route calls to the A group of finders, thereby restoring normal operation.

A FINDER BLOCK key can be used to completely "busy out" either the A or B group of finders. This provision is useful when making repairs or replacements in the finder control and distributor equipment of the A or B group, and when performing routine maintenance.

Connector Permanent Alarm.—The connector permanent alarm lamp (white) will light, and the common alarm buzzer will sound if a PERMANENT occurs in the switchboard. A permanent is any condition that causes a finder-connector link to be held in an operated position when it is not being used for talking or dialing purposes. This alarm is so designed that its action is delayed from 5 to 9 minutes.

Some of the causes of permanents are:

1. A dislodged handset.
2. Failure of calling party to dial or to complete dialing.
3. Failure of either party to hang up at the termination of a call.
4. A short-circuited line, either inside or outside of the switchboard.
5. A grounded line on the negative side, either inside or outside of the switchboard.

When the common alarm buzzer sounds and the connector permanent lamp is lighted, the following procedures will be helpful in locating the permanent.

1. Operate momentarily the PERMANENT RESET key to stop the alarm buzzer and extinguish the CONNECTOR PERMANENT ALARM lamp. However, both alarms will operate again if the trouble is not cleared within approximately 5 to 9 minutes.
2. Plug the hand test telephone explained later, (with button C depressed) in the test jack of each successive connector switch. In the case of a connector that is at normal, release button C and depress it again. This action should cause the connector to step up one step and then release. If the connector does not step, it is probably permanent. If a connector is off-normal and no dialing or talking is heard, release button C and challenge. If no answer is received, the connector is probably permanent.
3. When the permanent connector has been located, note the number of the switch and then examine the correspondingly numbered finder.
4. Determine the number of the faulty line by observing the position of the finder shaft and wiper assembly, and referring to the group A or group B finder banks designation card as the case may be. These designation cards are located inside the switchboard cabinet door.
5. Operate the line disconnect key of the faulty line. If the questionable finder releases, the trouble is not in the switchboard, but is at some point between the operated line disconnect key and the line station associated with that key. If the finder does not release, the trouble is in the switchboard.
6. Restore, when the trouble has been cleared, the line disconnect key to normal.

Ringing Machine Fail Alarm.—The ringing machine fail alarm lamp (red) will light, and the common alarm buzzer will sound if the ringing machine fails to start or fails to supply ringing current to the ringing transformer. This alarm is not provided with a delay interval. Ringing machine 1 and ringing machine 2 are each provided with an alarm lamp. The ringing machine transfer switch (mounted on the ringing machine panel) is operated in position 1 or position 2, to select the ringing machine to be placed in service.

When the ringing machine fail alarm is actuated, immediately operate the ringing machine transfer switch to the opposite position to start the idle ringing machine and restore service to the switchboard. The faulty ringing machine can now be repaired.

Common Alarm Buzzer. — The common alarm buzzer used in the alarm system provides an audible signal in addition to the previously described visual alarm signals. It is designed for bulkhead mounting and is conveniently located on the side of the automatic switchboard. The buzzer (type Z2) operates on 50-volt a-c power supplied by a transformer (mounted on the power panel) that supplies power to the dial telephone system. When a non-standard condition exists in the telephone system, the alarm buzzer operates immediately or after a predetermined delay, depending on the class of alarm. The newer switchboard buzzers operate from ship's power via a relay.

ACCESSORY EQUIPMENT

The dial telephone accessory equipment includes an attendant's cabinet (fig. 9-26) that is used to establish calls to and from shore exchanges when the ship is in port. The attendant's cabinet is interposed between the automatic switchboard (in the ship) and the shore exchange by means of two-way trunks to the automatic switchboard and two-way trunks to the shore exchange. The cabinet is provided with a dial telephone so that connection can be made with an automatic or a manual shore exchange.

ATTENDANT'S CABINET

The attendant's cabinet for a 100-line system (figure 9-27) consists of a steel enclosure designed for bulkhead mounting. The cabinet is divided into three compartments. The top compartment contains the two-way shore-line trunks and the terminal block. The center compartment contains the key panel, the handset, and the dial. A jack is provided for plugging in the headset. The bottom compartment contains the two-way local trunks and the equipment for the attendant's telephone circuit, the fuse panel, the terminal block, and a headset (stored in the lower left-hand corner). The top and bottom compartments are provided with two hinged doors each for access to the interiors. The center compartment is equipped with a hinged door for access to the attendant's operating equipment. This door swings forward to form a shelf or desk.

KEY PANEL. — The four two-way shore-line trunks from the top compartment and the four two-way local trunks from the bottom compartment each terminate in four associated lamp and key strips. The four lamp and key strips for the local trunks and the four lamp and key strips for the shore-line trunks are located on the left-hand righ-hand sides respectively of the key panel. The lamp and key strip for each local trunk contains a busy lamp (red), a call lamp (white), two shore trunk (cross-connecting) keys, a talk (answering) key, and a release key. Similar equipment is contained on the lamp and key strips for the shore-line trunks, except for the double-throw shore trunk keys. The final connections are established by the shore trunk keys located only on the local trunk strips.

The wiring of the local and shore-line trunks and the shore trunk keys is indicated by the single-line diagram in figure 9-28. As previously mentioned, two double-throw shore trunk keys are provided on each of the four lamp and key strips of the associated two-way local trunks. The upper shore trunk key has two positions designated TRUNK 1 and TRUNK 2, and the lower shore trunk key has two positions designated TRUNK 3 and TRUNK 4. All of the trunk 1 positions are connected in parallel with the shore-line trunk 1; all of the trunk 2 positions are connected in parallel with the shore-line trunk 2; and so on for the remaining key positions and shore-line trunks. The local trunk 1 is connected in parallel with the upper and lower shore trunk switches, so that local trunk 1 can be connected to either the trunk 1 or trunk 2 position by the upper shore trunk key or to either the trunk 3 or trunk 4 position by the lower shore trunk key. The remaining local trunks, 2, 3, and 4, each similarly connected to an upper and lower shore trunk key. Hence, any local trunk can be cross connected with any shore-line trunk, and vice versa. However, when a cross-connecting key and any local trunk is operated to a certain number, the local trunk is associated with the correspondingly numbered shore-line trunk. Hence, only one cross-connecting key should be operated to the same number at any one time.

A push-switch type release key is provided for each trunk. By means of the release keys, the attendant can release either end of a connection while holding the other end.

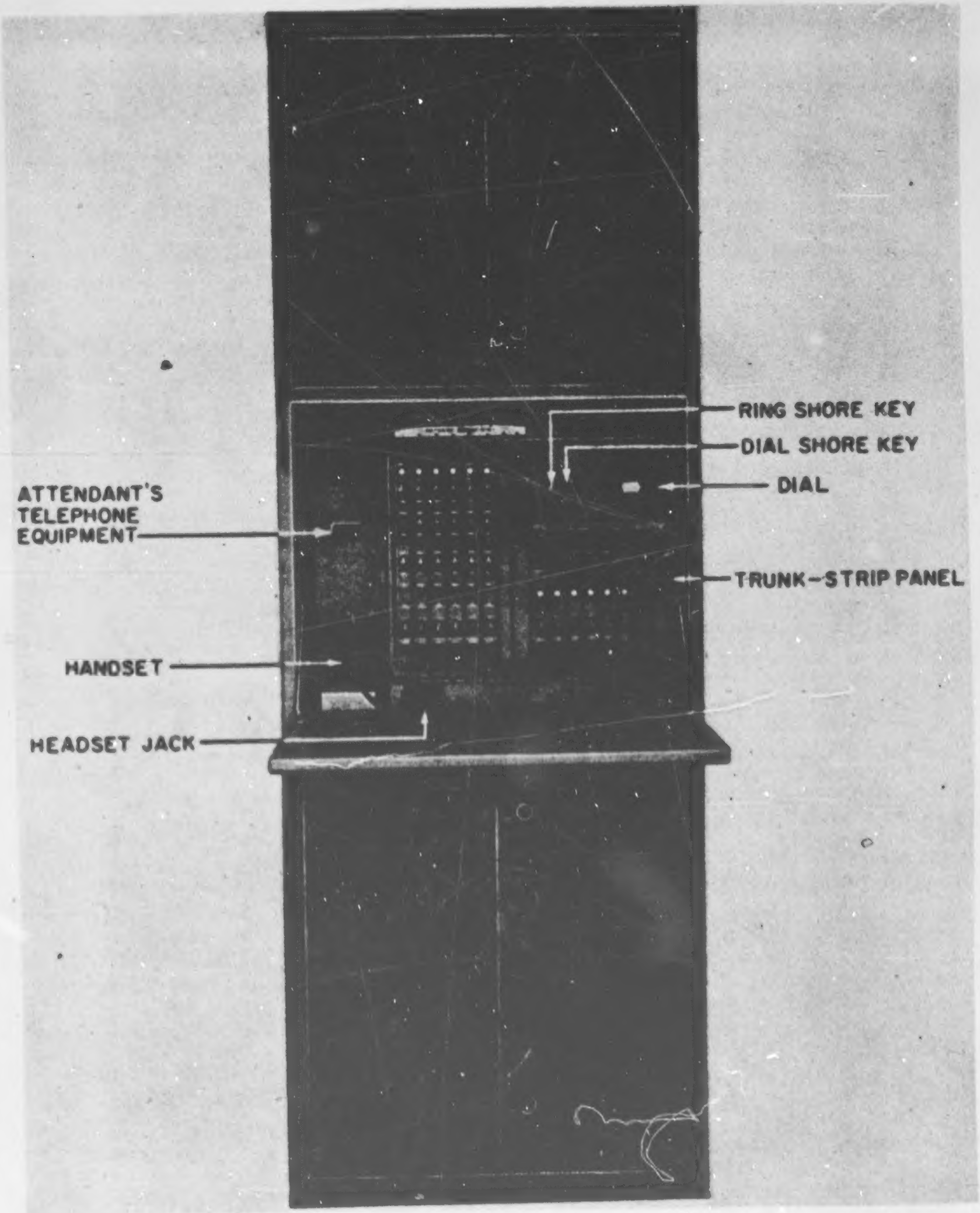
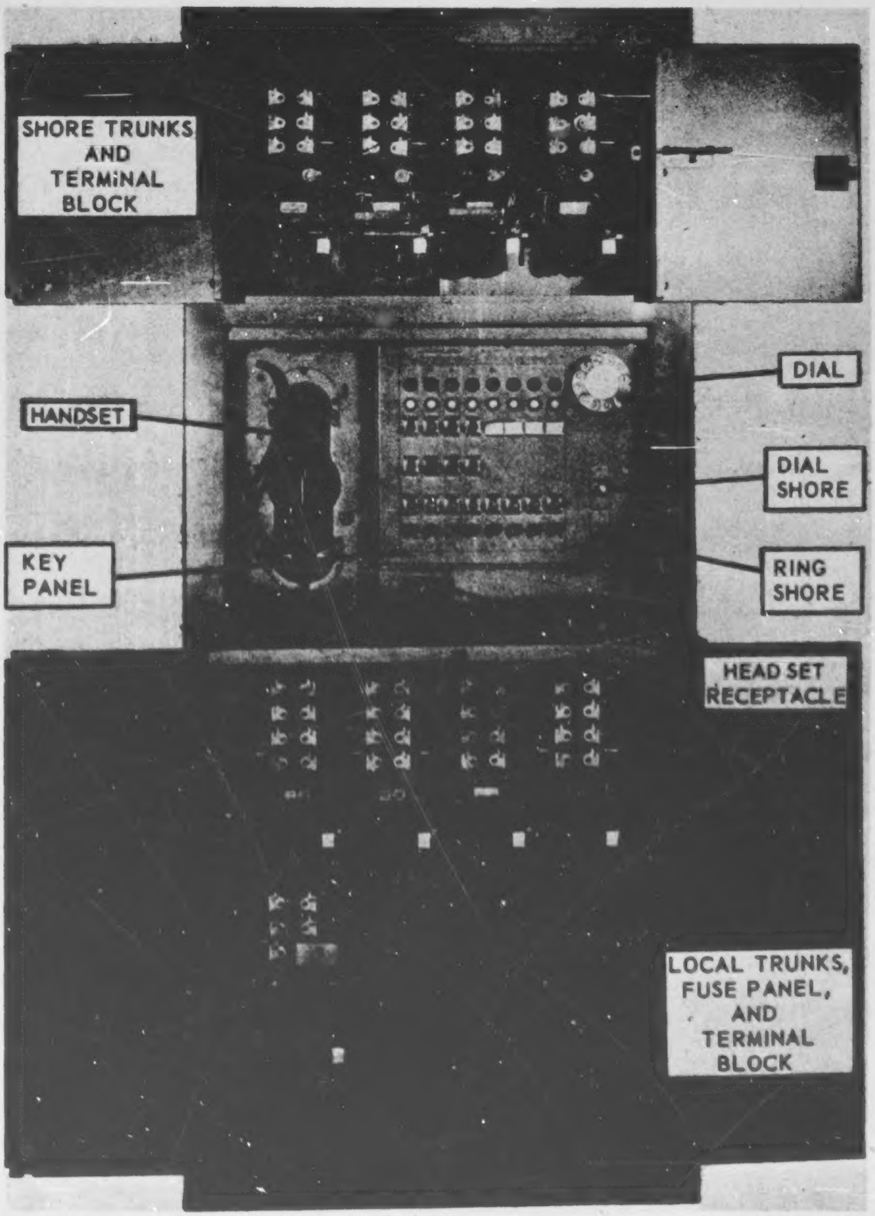
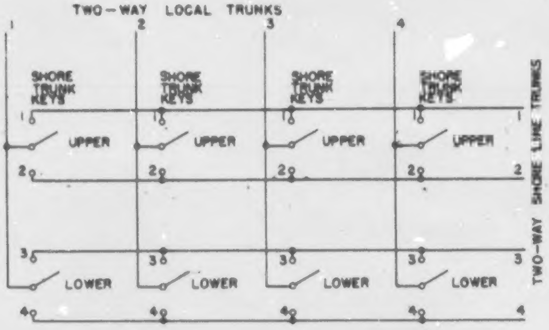

RING SHORE KEY
DIAL SHORE KEY
DIAL
ATTENDANT'S TELEPHONE EQUIPMENT
TRUNK-STRIP PANEL
HANDSET
HEADSET JACK
140.78

Figure 9-26.—Attendant's cabinet used with 100-line exchange.


SHORE TRUNKS AND TERMINAL BLOCK
DIAL
HANDSET
DIAL SHORE
KEY PANEL
RING SHORE
HEAD SET RECEPTACLE
LOCAL TRUNKS, FUSE PANEL, AND TERMINAL BLOCK

140.79

Figure 9-27.—Attendant's cabinet.



140.80

Figure 9-28.—Shore trunk key schematic.

A dial shore key and a ring shore key are located on the right of the trunk strips below the dial.

When a call is received on the local or shore-line trunks the corresponding CALL lamp lights and the common buzzer sounds. When the attendant answers by operating the TALK key, the CALL lamp is extinguished, the buzzer is silenced, and the BUSY lamp is lighted. When a shore-line disconnects, no action occurs. However, when the local station disconnects, the local CALL lamp lights again, the BUSY lamp remains lighted, and the buzzer sounds to signal the attendant. Thus, the two lamps provide CALL, BUSY, and DISCONNECT indications with an audible signal on the CALL and DISCONNECT indications. A shore-line DISCONNECT signal is not provided because of the many and varied types of shore exchanges that might be involved. However, the attendant is provided with a means for dialing over both the local and shore-line trunks, and for ringing on the shore-line trunk if the shore exchange employs a ringing magneto and local battery telephones.

HEADSET.—During busy periods the headset can be used by the attendant instead of the handset. When the headset is plugged into the jack located at the bottom of the panel, the transmitter and receiver are in the attendant's telephone circuit at all times, and the attendant can converse on any trunk that has the TALK key operated.

When the headset is plugged in (or the handset is removed) and any TALK key is operated, the buzzer will not sound to interrupt the attendant, but the lamps will function as usual to provide the required signals. However, the buzzer will sound if the attendant attempts to disconnect the headset or hang up the handset without answering all new calls and releasing all completed calls.

SHORE-LINE CONTROL SWITCH

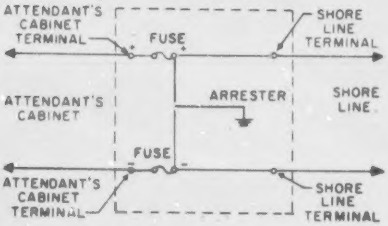
Each local trunk is associated with a line circuit (line relay) on the automatic switchboard. These line circuits can be used for regular local (shipboard) service when they are not being used for shore-line service. The shore-line control switch, mounted on the lamp and key panel of the automatic switchboard is provided to switch the attendant's cabinet in and out of service.

LIGHTNING ARRESTOR AND SHORE-LINE CONNECTION BOXES

Each set of shore-line telephone leads from the automatic switchboard passes through a lightning arrestor box, then ends in a shore-line connection box. The lightning arrestor box protects the telephone operator and telephone equipment in case lightning should strike the incoming telephone lines.

The lightning arrestor and shore-line connection boxes may be combined in several ways. The installations vary from ship to ship, and those mentioned here serve only as examples of the variety you may find in the fleet. On a large ship you are likely to find one arrestor box and one connection box on each side, port and starboard. Some small ships have only one lightning arrestor box in the circuit ahead of the lines that branch off to the port and starboard shore-line connection boxes. Normally, standard electrical connection boxes are used where the incoming shore-lines connect to the ship's lines. A recent practice that is gaining favor calls for the use of amphonel-type, multipin, jack-and-plug combinations. In such a case, the plug fits the shore-line connection box and the jack attaches to a portable cable which is run to the local shore-line connection box on the pier. Old installations also had the capability of taking on telegraph lines through the same connection box. The new boxes have a removable plug in the bottom of each box for inserting the cable.

Figure 9-29 shows the basic circuit arrangement for a typical lightning arrestor box. Each lead of the incoming line has a 5-ampere fuse and a set of carbon contacts in the line. On a massive surge, the fuse will blow to open the circuit to the automatic equipment, whereas the



140.81

Figure 9-29.—Shore connections.

carbon contacts will fuse together to provide a path to ground for the incoming potential.

FLEET ANCHORAGE COMMUNICATIONS

In order to facilitate telephone communications while at anchor many vessels have installed in their bows permanent cabling for connection to telephone equipped buoys. A portable telephone cable (TPU6) is used to make the connection.

The lightning arrester is used for personnel and equipment protection, while the communications panel (see plotters transfer panel chapter 6) serves to locate the lines.

POWER EQUIPMENT

The shipboard dial telephone system power equipment includes a motor generator set, a battery, and panel mounted control and protective devices. Power from the battery and generator is cabled to the panel fuses from which it is distributed to the various switchboard units.

The generator, battery, and switchboard are connected in parallel, with the system drawing power from the generator except during a generator or power failure, or when the system requirements exceed the capacity of the generator. During these abnormal occasions the battery supplies part or all of the required power.

The generator is capable of supplying 60 percent of peak busy hour load so that during these peak periods the battery supplies up to 40 percent of the power required to operate the system. This method of battery operation, except for the slight drain during peak loads, is called the float method of battery operation by which the battery is kept fully charged at all times.

Motor Generator Set

The automatic switchboard and associated apparatus require approximately 51.6 volts d-c to operate. The ship's IC switchboard Panel 1 supplies 450 volts a-c to a diverter pole motor generator set to achieve this requirement. In addition to providing the power for the system, the MG set also keeps the battery fully charged.

The motor is a squirrel-cage induction type designed to drive the generator at 1800 r.p.m. (fig. 9-30A).

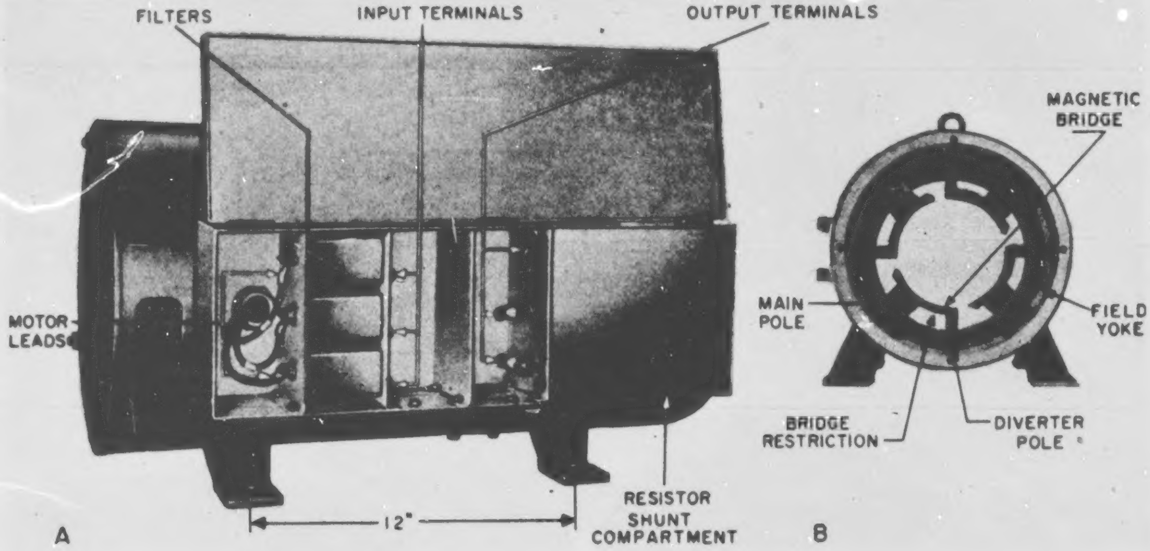
The generator is the diverter-pole type, and is designed to furnish 10, 25, or 50 amps at 56 volts of d-c power. The diverter-pole type field windings (fig. 9-30B) provide inherent voltage regulation, and thus tend to maintain the voltage at a constant level under conditions of load fluctuation.

Diverter Pole Generator

The diverter-pole type field windings (fig. 9-31A) include four main poles which are shunt wound (connected across the generator circuit). Associated with each pole is an interpole (the diverter pole) which is series wound (the armature coil and the interpole are wound in series with the load). The main pole and its associated interpole are connected by a magnetic bridge which includes a restricted section. The restricted section performs two functions: it limits the leakage from the main pole to the diverter pole, and it acts as a magnetic choke to regulate the magnetic flux passing the armature from the inner face of the diverter pole.

Figure 9-31A shows also the field under a no-load condition. Part of the magnetic flux resulting from the current in the shunt winding of the main pole is diverted through the diverter pole via the magnetic bridge. This diverted flux is shown in dotted lines. Since there is no load, the series winding on the diverter pole has no magnetomotive force.

At 50 percent load as shown in figure 9-31B the flow of current through the series winding of the diverter pole increases, creating a magnetomotive force for the diverter pole. The shunt winding of the main pole and the series winding on the diverter pole are in opposition, therefore as the load on the generator increases, the flux provided by the diverter pole offers increased opposition in the magnetic bridge to the flux from the main pole winding. With the magnetic bridge blocked, the greater portion of the flux from the main field is sent through the armature. It can be seen that as the load increases, the armature cuts an increasing number of lines of force, and the level of generated voltage rises accordingly, thereby overcoming the IR and



140.87

Figure 9-30.—Motor-generator set.

cross-magnetization losses to hold the voltage at a constant level.

The figure indicates increasing flux from the diverter pole windings. Note that there are fewer lines of force (dotted lines) from the main pole winding through the magnetic bridge and diverter pole, and that increasing lines of force (unbroken lines) are being sent into the armature path.

During full load conditions, (fig. 9-31C) flux from the diverter pole almost entirely blocks the passage of flux from the main pole through the magnetic bridge, and therefore almost all of the flux from the main pole winding is sent into the armature's path. In this manner the level of the voltage is raised sufficiently to compensate for internal losses, and the output voltage is maintained at the desired constant level.

As the generator is subjected to an overload condition (fig. 9-31D), the ampere turns of the diverter pole will, at some period, equal those in the main field. At this point, flux from the diverter pole will completely block the magnetic bridge, and all main pole flux will be diverted into the armature path. With the load increasing, but before the danger level, diverter pole flux soon becomes strong enough to block the passage of the main pole flux to the armature. This condition, shown as a decrease in the lines of force in the armature path, will result in a drop in generator voltage. It can be seen therefore that the diverter pole generator protects itself against the excessive current condition of an overload.

Battery

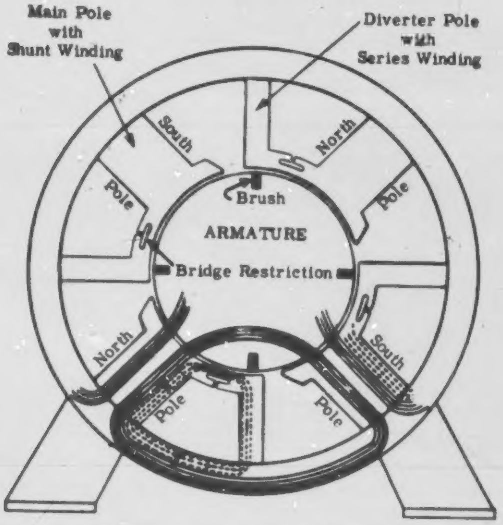
The battery used with the automatic switchboard is a standard rack of 24 cells as explained in Basic Electricity, NavPers 10086 (latest edition).

Power Control Panel

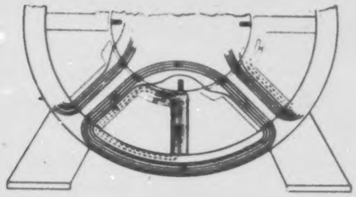
Located on the power control panel are the various controls associated with the power supplying units and the connections for these units. No attempt will be made to explain these varying controls, however figure 9-32 is a simplified diagram of the connection of the motor generator and the battery to the switchboard.

Connection

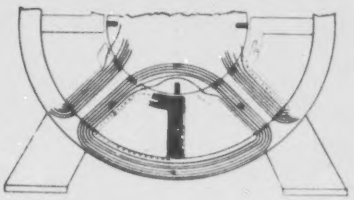
The connection of the battery and the generator is through the contacts of the reverse


Main Pole
with
Shunt Winding
Diverter Pole
with
Series Winding
South
North
Pole
Pole
Brush
ARMATURE
Bridge Restriction
North
South
Pole
Pole

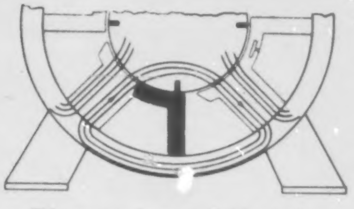
A Diverter-pole type field winding at no load, partial pictorial schematic



B Diverter-pole type field winding at 50% load, partial pictorial schematic



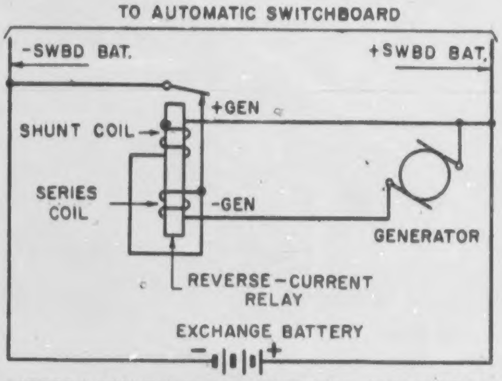
C Diverter-pole type field winding at full load, partial pictorial schematic



D Diverter-pole type field winding at overload, partial pictorial schematic

140.88

Figure 9-31.—Motor-generator field.


TO AUTOMATIC SWITCHBOARD
-SWBD BAT.
+SWBD BAT.
+GEN
SHUNT COIL
SERIES COIL
-GEN
GENERATOR
REVERSE-CURRENT RELAY
EXCHANGE BATTERY
-
+

BATTERY CONNECTED TO GENERATOR (REVERSE-CURRENT RELAY OPERATED), PARTIAL SCHEMATIC

140.89

Figure 9-32.—Power connection.

current relay. The switchboard draws power from the battery when the reverse current relay is not operated, and draws power from the generator, or the generator and battery when the reverse current relay is operated as shown (fig. 9-32). The reverse current relay acts as a contactor for making the connection between the generator and the battery, and also as a protective device to prevent current from flowing from the battery to the generator when the generator voltage has dropped below that of the battery.

MAINTENANCE

Dial telephone system maintenance includes periodic tests and inspections, lubrication cleaning, and troubleshooting and repair. Test equipment, special tools, and special lubricants and charts are provided with each system, and detailed maintenance instructions are included in the manufacturer's technical manual.

Cleanliness is essential due to the low voltages and currents involved. Dirt and dust can cause insulation failures, and high resistance or partially open contacts. Use a vacuum cleaner for removing dirt and dust from the switchboard equipment. Relay contacts may be cleaned by pulling a strip of bond paper between them. Use a burnishing tool to clean pitted contacts. The adjustable parts of the relays and switches are delicate and require the use of special tools to adjust them. Do not attempt to adjust a switch or relay until it has been definitely determined that adjustment is necessary. When adjustment is necessary, study the manufacturer's adjustment instructions, and follow them carefully.

Periodic ground tests should be made on all telephone lines at least monthly, or as required by current maintenance instructions. If a 500-volt megger is used to make the tests, test each conductor to ground only. Do not test between the twisted pairs as the 500 volts may damage the capacitors in the equipment.

TELEPHONE INSPECTIONS

Periodically check the speed of all telephone dials by dialing the digit 0. The dial should return to its normal position in approximately 1 second. Inspect and tighten all mouthpieces and earpieces; replace if broken. Replace frayed, worn, or noisy cords. To check for a noisy cord, roll the cord back and forth between the hands while listening for a clicking or crackling noise in the receiver. Conduct a transmission test over each telephone by talking with another person.

TELEPHONE LINE STATION REPAIRS

In general, when it is necessary to work on a telephone it should be taken out of service by disconnecting the L1 and L2 line wires. The line wires can be disconnected in the type A telephone at the cord terminal block located at the end of the desk set cord, and in the types C, F, and G telephones at the terminal strip inside the housing. This procedure prevents the unnecessary operation of the automatic switches that seize and hold busy a conversation link at the switchboard. To prevent reconnecting line wires in reverse, they should be marked when disconnected.

Removing the Dial Card

The dial card is removed by inserting the special dial tool under the escutcheon ring (fig. 9-4), near the digit "5" finger hole. Press the tool down against the locking lever underneath the card and move the tool counterclockwise to the digit "6" finger hole. This action unlocks the card assembly. Lift the escutcheon ring at the digit "6" finger hole with the tip of the tool and withdraw the card assembly. The escutcheon ring, the celluloid cover, the dial card, and the dial card clamping plate will release as one assembly. The parts of this assembly can be released by turning the assembly clamping plate in a counterclockwise direction. Notice the relative position of the parts as they are removed so that they can be easily reassembled.

The components of the card assembly are reassembled by placing the celluloid cover and then the dial card into the escutcheon ring. Place the dial card clamping plate over the dial card and turn the clamping plate in a clockwise direction to engage the tongue, thereby locking the assembly. Mount the card assembly on the dial, with the locking lever on the finger plate pointed midway between digits "6" and "7". Insert the small lug on the escutcheon ring into the slot located above the finger stop and press the assembly down into the finger plate. Hold the assembly in place and insert the dial tool under the escutcheon ring near the digit "7" finger hole. Press the tool down against the locking lever underneath the card and move the tool in a clockwise direction to the digit "6" finger hole, thereby locking the card in pace. Remove the tool.

Replacing the Dial

To replace the dial of any type of telephone expose the interior, as previously described, and disconnect the four conductors at the rear of the dial. Remove the three screws and lockwashers that hold the dial in place and lift out the dial. Mount the new dial and replace the lockwashers and screws. Connect the four conductors to the dial in accordance with the circuit label inside the telephone. Dials are properly adjusted and lubricated before shipment and should operate for long periods of time without attention. However, if minor adjustments are required the proper procedures are listed in the manufacturer's technical manual.

Replacing the Cords

A handset or cord on a telephone can be readily replaced because cords are carried (already made up) in the spare parts box. When replacing a handset or cord, refer to the circuit label inside the telephone or make a wiring sketch so that the cord can be connected properly. All wires are color coded, and the connections are made by screw type terminals. Always anchor the tie cord securely, using sufficient slack in the conductor wires so that no strain is placed on the wires.

Replacing the Transmitter and Receiver Units

The transmitter and receiver are both of the capsule type and thus are completely enclosed self-contained units. These units cannot be opened without damage. In the event of trouble the entire unit must be replaced.

The transmitter unit is held in place in the mounting cup by two retaining spring clips and is secured by the mouthpiece. Connections to the electrodes are through springs. To remove the transmitter unit, hold the handset in a horizontal position (facing up) and unscrew the mouthpiece. If the hand slips, wrap a piece of friction tape around the mouthpiece to provide the necessary friction. Lift the transmitter unit out of the housing, with the fingers engaging the outer edge of the unit between the two retaining spring clips.

To replace the transmitter unit, hold the handset in a horizontal position, as previously explained. Insert the outer edge of the unit against the movable retaining spring clip (located in the cup) and snap into place, pressing only on the outer edge of the transmitter. Then screw on the mouthpiece.

The receiver unit is held securely in place by the ear cap. Connections to the electrodes are through springs. To remove the receiver unit, hold the handset in a horizontal position (ear cap facing up) and unscrew the ear cap. Place the hand over the receiver housing and turn the handset over. The receiver unit will drop out and into the hand.

To replace the receiver unit, hold the handset in a horizontal position, as previously explained. Place the receiver in the cup and screw on the ear cap.

Some of the common dial telephone faults are discussed briefly below.

NOISY CONNECTIONS.—Noisy connections are caused by partial shorts or grounds on the line, worn handset or desk set cords, noisy transmitters, and loose connections in the telephone.

CLICKS IN RECEIVER.—Clicks in the receiver while dialing are usually caused by failure of the shunt springs to make contact when turning the dial. If this condition is not corrected after cleaning the contacts, look for a broken shunt spring connection.

CALLED STATION DOES NOT RING.—If the bell at a called station does not ring, the fault can be caused by an open ringer coil or capacitor, an improper adjustment of the ringer, or reversed or loose connections at the ringer terminals. Also, the bell will not ring properly if the gongs have become loose or if the position of the gongs has shifted with respect to the clapper.

CANNOT ANSWER.—If a party at a called telephone is signaled but cannot be heard, the fault can be caused by a shorted transmitter or a shorted contact of the dial shunt springs. Also, if the hook switch springs fail to operate, the ringer will not be cut off when the handset is removed at the called station.

CANNOT HEAR WELL.—If a telephone has poor reception, the trouble may be caused by improper contact of the contact springs in the receiver housing, a loose receiver cap, a worn receiver cord, or loose connections inside the telephone.

CANNOT BE HEARD WELL.—If a telephone has defective voice transmission, the fault is probably in the transmitter unit. To loosen the carbon granules, hold the handset in a horizontal position and shake it, using a circular motion. If the cabon granules are not loosened by this method, strike the transmitter end of the handset sharply with the palm of the hand. Also, check the contact springs in the transmitter for a tight, clean connection to the unit.

CANNOT CALL.—If a call cannot be made from a telephone, first determine if the line relay operates when the handset is removed at the calling station. If the line relay does not operate, short circuit the line terminals at the switchboard. If the line relay now operates, check for an open line between the switchboard and calling telephone.

WRONG NUMBERS.—The most frequent cause of wrong numbers is the impulse springs in the dial being out of adjustment or bent. As a consequence, the speed of the dial is reduced, resulting in wrong numbers. Another frequent cause of wrong numbers is jiggling the cradle switch before starting to dial. Moving the cradle switch up and down rapidly results in a series of impulses similar to those sent out by the dial. Keeping the dialing finger on the dial while it is restoring to normal may also result in wrong connections.

TESTING EQUIPMENT

Testing equipment is provided for use in detecting and locating nonstandard conditions in the dial telephone system. This equipment comprises (1) a line disconnect key panel (discussed earlier in this chapter), (2) a hand test telephone, (3) linefinder-connector test set, (4) a current flow test set, and (5) a line routiner.

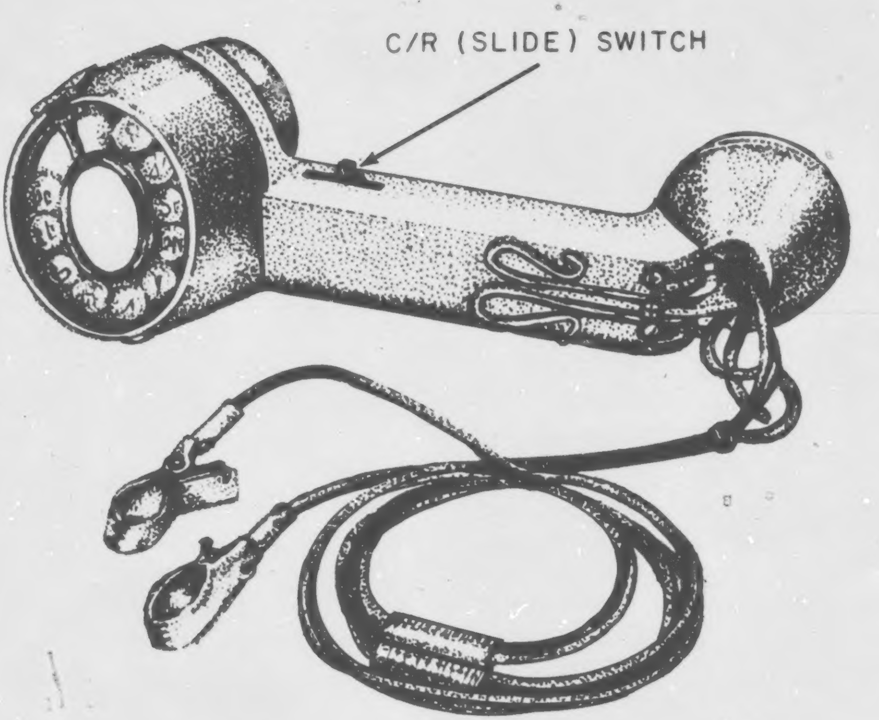


Figure 9-33.—Hand test telephone.

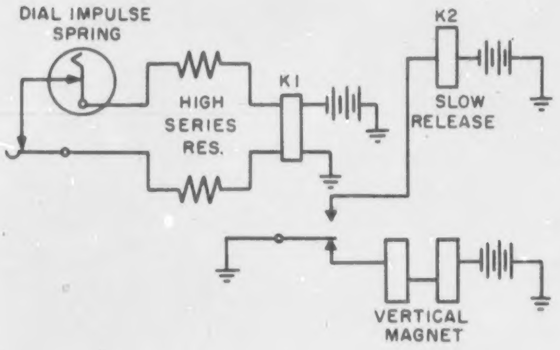
A knowledge of the testing equipment is necessary to keep the telephone system operating at a maximum efficiency. Therefore, the more important test equipment listed above will be discussed here.

Hand Test Telephone

The hand test telephone is mounted on the rear of the finder board by a spring clamp. The hand test telephone can be used independently or in conjunction with the test set, depending on the type of tests to be conducted.

The hand test telephone (fig. 9-33) consists of a conveniently shaped handle with a transmitter at one end, and a receiver and dial placed back-to-back at the other end. A 2-conductor test cord with a test plug is connected to the transmitter end of the case. Two pushswitches marked C and R respectively are located externally on opposite sides of the handle toward the receiver end (a slide switch on newer designs). A capacitor, an impedance coil, and a resistor are mounted inside the case.

When pushswitch C is depressed, a capacitor is connected in the transmitter circuit. The capacitor cuts off the talking circuit to permit listening only, and also prevents interference with dial pulses when plugging in the hand test telephone. Pushswitch C is released when dialing the switch being tested, or, if the switch is already in use, when using the hand test telephone to talk to either party.



27.210
Figure 9-34. — High loop resistance circuit.

When pushswitch R is depressed, a 1200-ohm resistor is connected in series with the transmitter. This resistor is used to test the operation of Strowger switches. However, this button is not used normally because the hand test telephone is provided with a 1000-ohm resistor (in addition to the 1200-ohm resistor) that automatically provides a high resistance in series with the line when testing Strowger switches.

Line Routiner

The line routiner is test equipment used in testing lines of the shipboard dial telephone system. The routiner consists of two units — a test connector and a portable line test set. The test connector is furnished with repair parts, and is to be jacked into a connector position when the line routine test is made.

TEST CONNECTOR. — The test connector is a Strowger switch mechanism which in appearance is similar to a regular connector. The circuit of the test connector, however, differs considerably from that of a regular connector in that (1) the test connector is actuated to elevate and rotate its wipers without pulses from a dial, and (2) the circuit of the test connector includes facilities for testing for the presence of line faults.

LINE TEST SET. — The line test set includes an ohmmeter, a rheostat, three keys, and a test cord and plug. The set plugs into the test jack on the test connector and may be connected either before the testing starts or when the connector stops because of a line fault. The line test set determines the nature and resistance of the fault.

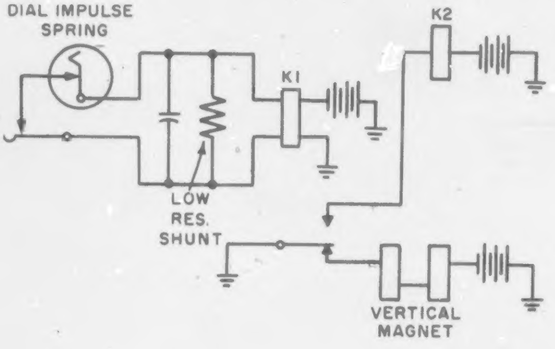
A fault which measures between 10,000 and 50,000 ohms will not interfere with the operation of the telephone apparatus but it does indicate a possible future source of trouble and should be corrected. A fault which measures less than 10,000 ohms will interfere with dialing.

LOOP RESISTANCE. — For successful operation of automatic switching equipment, lines must be maintained within certain limitations of line loop resistances. Line loop resistance is the metallic resistance of the line conductors, and is the resistance measured between the automatic switchboard and the telephone instrument (exclusive of the instrument).

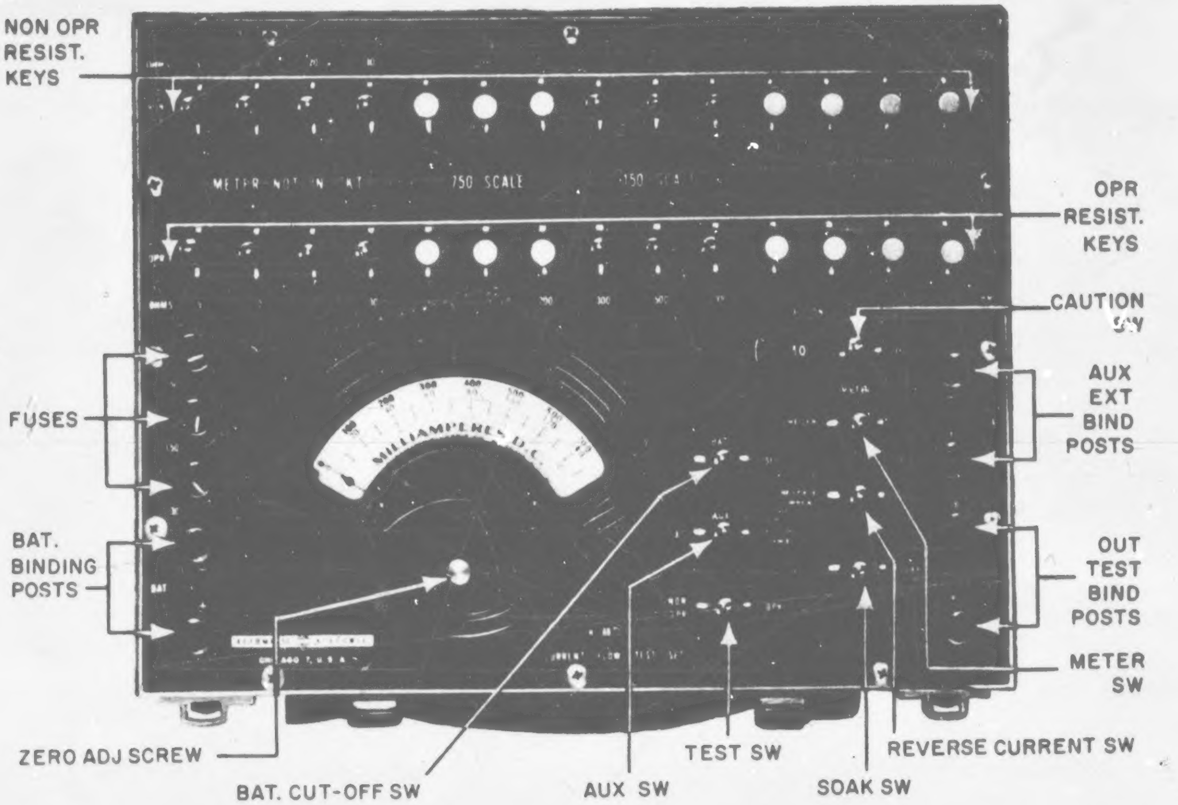
There are two types of line loop resistance — high loop and low loop.

The effect of high fault loop resistance may best be analyzed by considering a line of rather high series (line loop) resistance such as shown in figure 9-34. When relay K1 operates, it sends a pulse of current to slow-to-release (SR) relay K2, and when relay K1 releases, it sends a pulse of current to the vertical magnet. If there is too much resistance in the line, relay K1 will be slow to operate and will fall away quickly on dial impulse because of the low magnetic saturation of its core. Since relay K1 falls away quickly, the pulse of current to relay K2 is too short, and relay K2 will not remain operated. The vertical magnet, on the other hand, gets too long a pulse (sometimes called a "heavy" pulse).

The second type of line fault loop resistance is low loop resistance. If there is negligible line loop resistance and low insulation resistance (fig. 9-35), a high leakage current (which constitutes a low-resistance shunt) results, and line



27.211
Figure 9-35. — Low loop resistance circuit.


NON OPR RESIST. KEYS
OPR RESIST. KEYS
METER NOT IN CKT
750 SCALE
150 SCALE
CAUTION SW
AUX EXT BIND POSTS
FUSES
MILLIAMPERES D.C.
OUT TEST BIND POSTS
BAT. BINDING POSTS
METER SW
ZERO ADJ SCREW
TEST SW
REVERSE CURRENT SW
BAT. CUT-OFF SW
AUX SW
SOAK SW

27.212

Figure 9-36.—Current-flow test set.

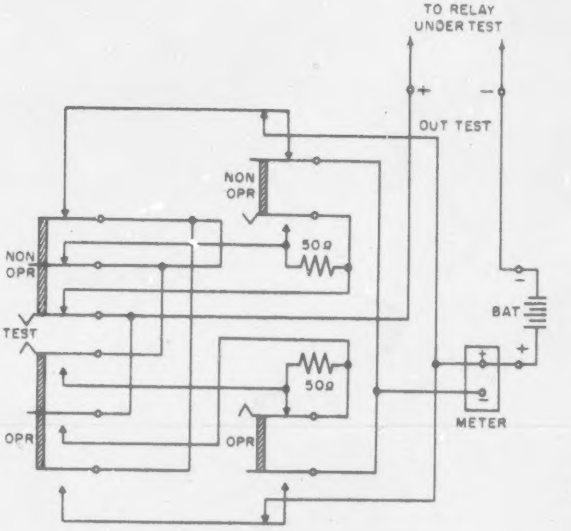
relay K1 is held partly magnetized even after the dial impulse springs have opened the circuit. Thus, relay K1 operates too fast at the beginning of a dial pulse and releases too slowly at the end of a dial pulse. The shunt tends to maintain relay K1 operated when the dial impulse springs break because of the battery current through the shunt. Since relay K1 remains operated for a relatively long time, the vertical magnet gets too short a pulse ("light" pulse).

Current-Flow Test Set

The successful operation of automatic switchboard circuits requires that the relays in such circuits perform to exact operate and nonoperate values. The operate and nonoperate requirements for each relay in a given circuit are listed in the manufacturer's technical manual.

To determine that a relay operates within the required limits, it is preferable to test the relay with known values of current. The current-flow test set (fig. 9-36), is a means by which known values of current are directed to the relay under test. The ammeter on the test set indicates the value of the current in the test circuit, and the key-controlled resistances are a convenient means by which the flow of current in the test circuit is regulated. The test set has facilities for connecting a total of 42,215 ohms into the test circuit, 22,215 ohms be means of the resistance keys, and 20,000 ohms by operation of the auxiliary switch.

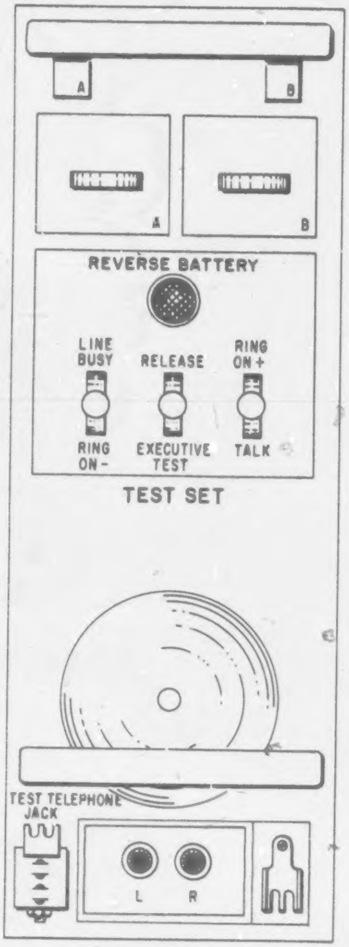
CURRENT-FLOW TEST CIRCUIT.—The circuit for the current-flow test set is always brought through the test switch regardless of how the set is used. Connections to the relay under test are always made at +OUT TEST



27.213
Figure 9-37.—Current-flow test set circuit.

which means the test circuit is not closed until the test switch is operated either to OPR or NON OPR. A typical test circuit is shown in figure 9-37.

Assume that a relay winding is connected across the OUT TEST binding posts, and that a battery is connected to the BAT binding posts. Also assume that the BAT key (not shown) is at normal, that the 50-ohm NON OPR resistance key is operated, and that the test switch is thrown to NON OPR. The test circuit is from battery on the - BAT binding post, through - OUT TEST and the winding of the relay under test. The circuit continues back through + OUT TEST, through the first pair of make springs in the nonoperate section of the TEST switch, and through the NON OPR 50-ohm resistance, through the second pair of make springs in the nonoperate section of the TEST switch, through the third pair of make springs in the nonoperate section of the TEST switch, and through make springs on the NON OPR 50-ohm resistance key, to the negative terminal on the meter, through the meter and finally back to the positive battery on the + BAT binding post. This is the basic test set circuit and, as may be seen, the meter will measure the current flowing through the winding of the relay. The current may be increased or decreased by operating additional resistance keys.



140.132
Figure 9-38.—Linefinder-connector test set.

The main function of the current-flow test set is to provide the means by which current of a known value may be directed to the relay under test. The test set can further provide a means for directing a "saturate" current to this relay and for reversing the polarity of current flow in the test circuit without changing any leads. Moreover this test set may serve as a resistance box or a d-c milliammeter to measure current less than 750 ma.

Linefinder-Connector Test Set

The test set (fig. 9-38) is used for testing the operation of connector switches. In the test setup, the set is connected to a switch by a patch cord, and the hand test telephone is plugged into the test set. The tests are made by dialing the exchange test number 29 on the hand test telephone, and operating the switches on the test set to check for ring, ringback, line busy, executive-right-of-way, transmission (talk), and proper release of the connector.

CHAPTER 10

DIAL TELEPHONE SYSTEMS, PART II

In response to the requirements for an expandable automatic dial telephone system which incorporated the features of flexibility, compactness, and reliability, the Marine Dialmaster Model MDM 200/700 telephone system was developed. The system is able to provide station-to-station communications via automatic dial telephone lines while at sea, and may be used with commercial telephone networks by way of ship-to-shore lines in port.

The main assemblies of the MDM 200/700 installation are one system cabinet and from two to seven identical switchboard cabinets. The line capacity of the system can be increased from 200 to 700 lines, in 100-line increments, simply by adding switchboard cabinets and associated cabling. Thus, a 200-line system initially installed can later be expanded to 300 lines, or to its maximum capability of 700 lines, without disrupting the initial installation. The number of simultaneous calls the system can handle is equivalent to 15% of the lines provided. As an example, a 200-line system is capable of handling 30 calls at any one time.

The system can be used with any two-wire telephone set, manufactured in the United States, which employs break-type dialing (a dial which interrupts the current flow). The compactness of the system is due to modular construction techniques. All electromechanical and solid-state switching circuits as well as all power equipment are mounted on a single equipment rack.

DESCRIPTION OF EQUIPMENT

The MDM 200/700 system is a modular, electromechanical system using rotary stepping switches and XY-Universal switches as the basic switching components. The system is comprised of one system cabinet (fig. 10-1) and from two to seven switchboard cabinets (fig. 10-2). An attendant's cabinet (fig. 10-3) provides an interface between ship lines and shore installations when the ship is in port.

Cabinets and Modules

Each cabinet (system or switchboard) consists of one rack of equipment shock mounted in a rigid cabinet assembly. The cabinet circuit modules, which are accessible through front and rear doors, plug into the framejack panel and contain all the switching circuits necessary for system operation. Two XY-Universal switches are associated with each of the fifteen finder/connector circuit modules used in each switchboard cabinet. These switches mount in cells located on the front of the frame and plug into the associated finder/connector circuit modules. The line connection panels are mounted directly to the switchboard frame (fig. 10-2A). These panels provide the means for connecting the switchboard to the ship's cables. Screw-type terminals are provided for all connections allowing line-number changes to be readily accomplished.

MAIN ASSEMBLIES OF THE SWITCHBOARD CABINET

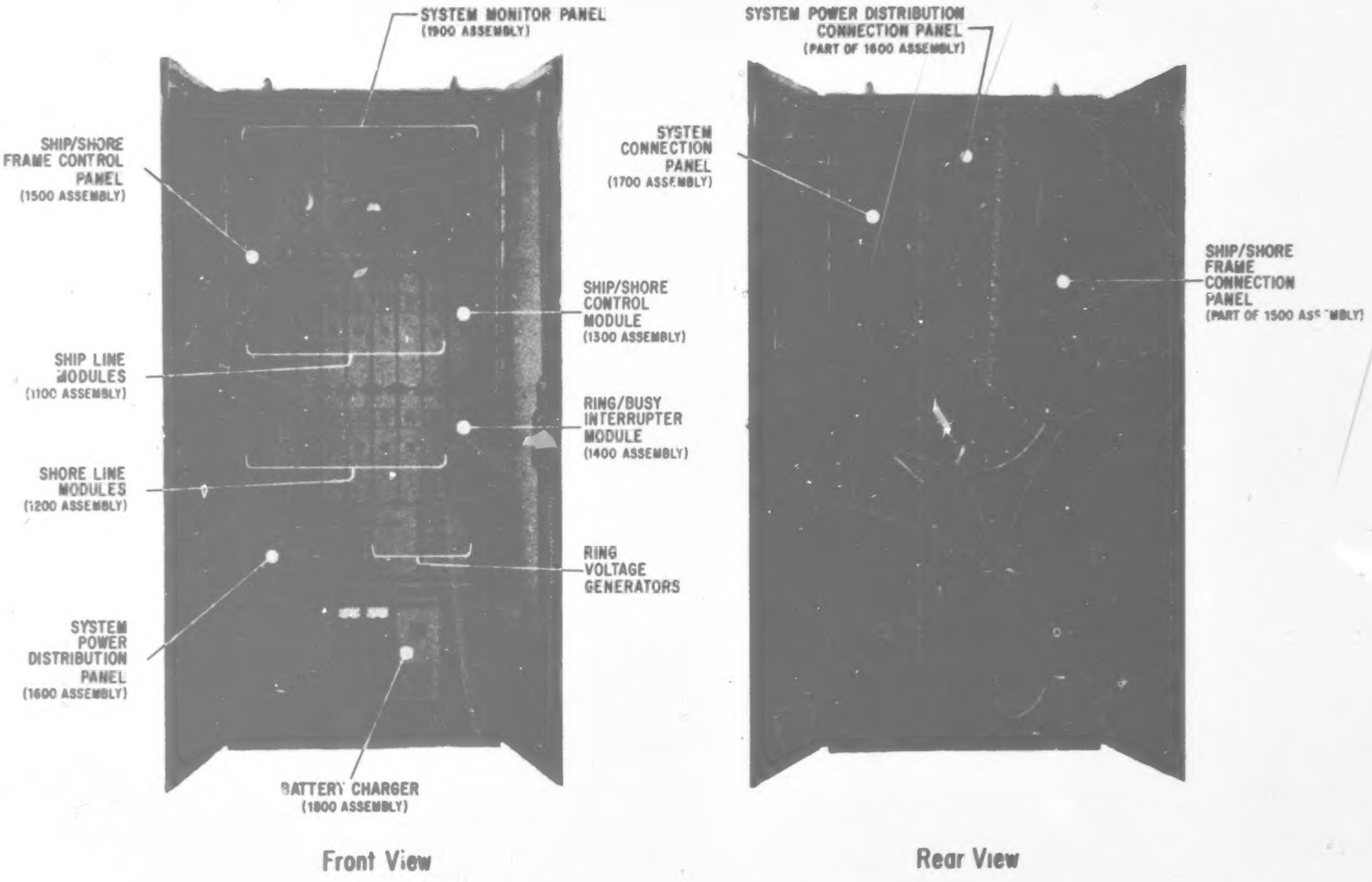
There are nine main assemblies in the MDM 200/700 system. Some perform similar functions to the Automatic Electric Strowger telephone system. Each has both a name and number designation.

Common Control Panel (100 Assembly)

The common control assembly consists of six separate, though related, circuits. The main function of the 100 assembly is to provide timing for finder action requests and to extend finder request ground (positive signal voltage) to the finder allotter. This assembly also provides dial tone and busy tone for the system.

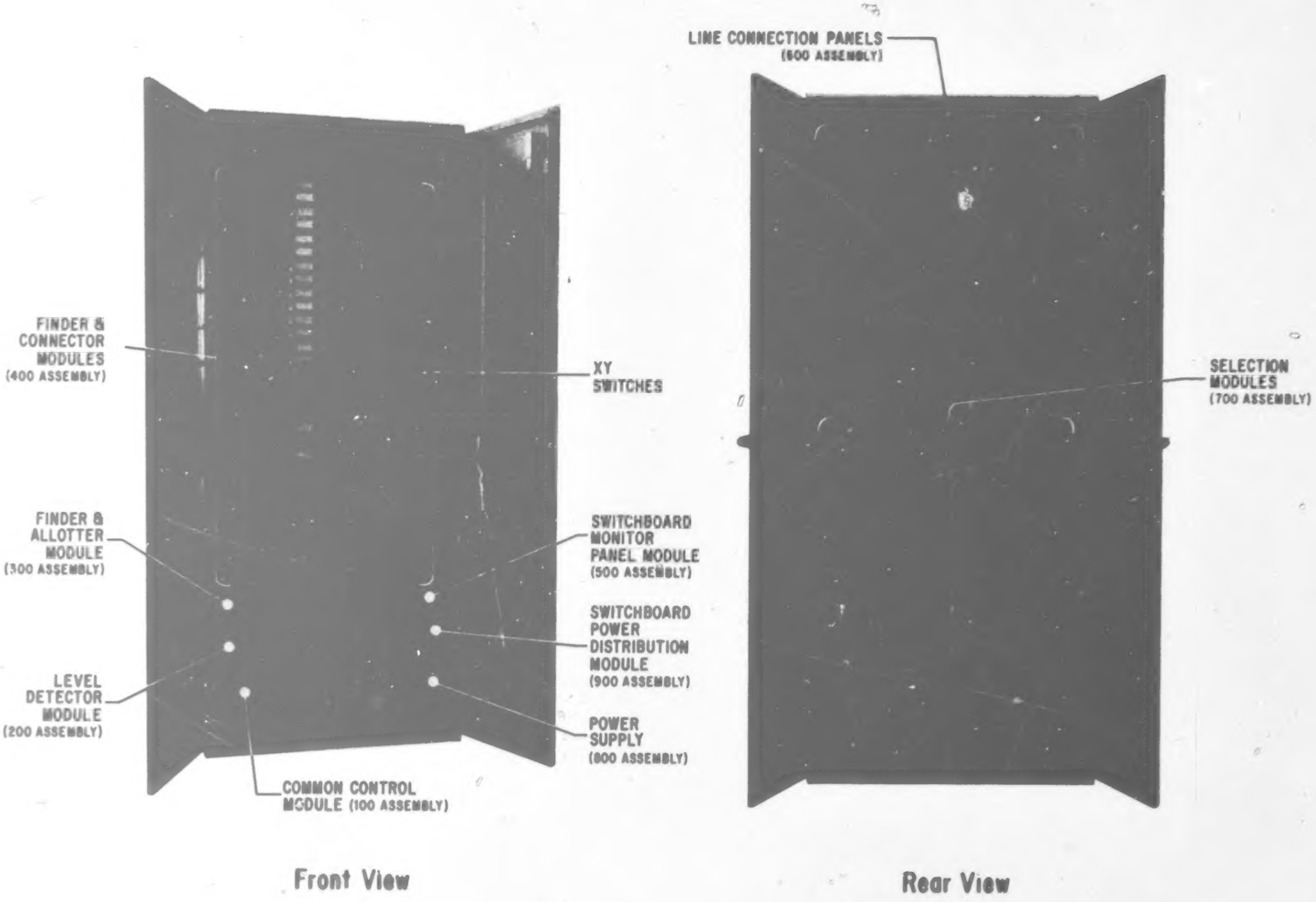
Level Detector and Alarm Circuitry (200 Assembly)

The level detector panel contains ten identical level detection circuits, one for each system level,


SYSTEM MONITOR PANEL
(1900 ASSEMBLY)
SHIP/SHORE FRAME CONTROL PANEL
(1500 ASSEMBLY)
SHIP/SHORE CONTROL MODULE
(1300 ASSEMBLY)
SHIP LINE MODULES
(1100 ASSEMBLY)
RING/BUSY INTERRUPTER MODULE
(1400 ASSEMBLY)
SHORE LINE MODULES
(1200 ASSEMBLY)
RING VOLTAGE GENERATORS
SYSTEM POWER DISTRIBUTION PANEL
(1600 ASSEMBLY)
BATTERY CHARGER
(1800 ASSEMBLY)
Front View
SYSTEM POWER DISTRIBUTION CONNECTION PANEL
(PART OF 1600 ASSEMBLY)
SYSTEM CONNECTION PANEL
(1700 ASSEMBLY)
SHIP/SHORE FRAME CONNECTION PANEL
(PART OF 1500 ASSEMBLY)
Rear View

140.162

Figure 10-1.—System cabinet.

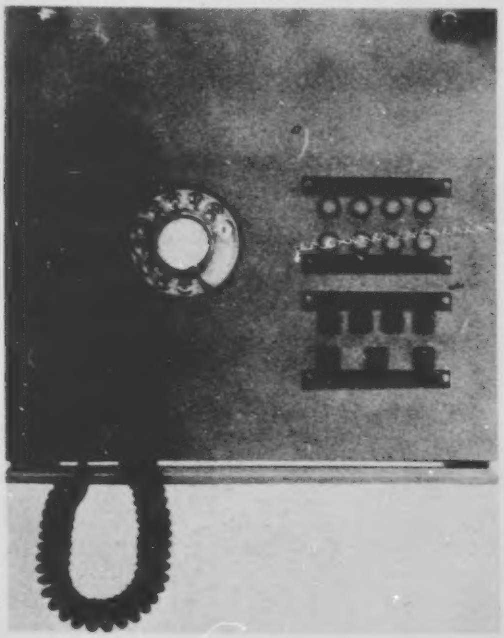

FINDER & CONNECTOR MODULES (400 ASSEMBLY)
XY SWITCHES
FINDER & ALLOTTER MODULE (300 ASSEMBLY)
SWITCHBOARD MONITOR PANEL MODULE (500 ASSEMBLY)
SWITCHBOARD POWER DISTRIBUTION MODULE (900 ASSEMBLY)
LEVEL DETECTOR MODULE (200 ASSEMBLY)
POWER SUPPLY (800 ASSEMBLY)
COMMON CONTROL MODULE (100 ASSEMBLY)
LINE CONNECTION PANELS (600 ASSEMBLY)
SELECTION MODULES (700 ASSEMBLY)

Front View

Rear View

140.163

Figure 10-2.—Switchboard cabinet.



140.164

Figure 10-3.—Attendants console.

and major and minor alarm circuits. The function level of the detector is similar to that of the start level mark system in the Automatic Electric system.

Finder Allotter Panel (300 Assembly)

The finder allotter panel, also referred to as the link allotter, contains fifteen identical circuits, one for each finder circuit. The circuit is very much the same as the finder-distributor relays in the Automatic Electric system, as it is used to select the next idle finder in the system.

Finder/Connector Panel (400 Assembly)

The finder/connector panel, also referred to as a "link", is made up of two main sections: the finder circuit where linefinding is accomplished and the connector circuit where connection to the calling line is accomplished. The transmission path is established in this assembly between the calling and the called telephones.

Switchboard Monitor Panel (500 Assembly)

The switchboard monitor panel contains three alarm signaling circuits which react to different alarm conditions. The panel also contains a jack for the systems test number plus switches and indicator lights used to control audible and visual alarms.

Line Panel (600 Assembly)

There are ten line panels in each switchboard cabinet. Each panel provides connections and switching facilities for one level of ten telephones. The line disconnect switches are located in this panel, which is also where a station can be wired for executive-right-of-way or become part of a line hunt group.

Selector Panel (700 Assembly)

There are five selector panels, each containing three identical selector circuits. The selector circuit provides the means by which a telephone station can call any other station in the system. This assembly performs the same function as the selectors in the AE system.

Power Supply (800 Assembly)

The power supply unit uses a single phase, full-wave rectifier with choke input for regulation and diode surge current protection. A choke together with filter capacitors provide low ripple d-c power. Each switchboard contains its own power supply unit.

Power Distribution Panel (900 Assembly)

This assembly distributes d-c power to equipment in the switchboard cabinet.

MAIN ASSEMBLIES OF THE SYSTEM CABINET

The system cabinet consists of nine main assemblies: 1100, 1200, 1300 through 1900. Four of these (1100, 1200, 1300, and 1500) are associated with the operation of the attendant's console.

Ship Line Modules (1100 Assembly)

There are eight identical ship line modules, one for each ship line connected to the attendant's console.

Shore Line Modules (1200 Assembly)

This assembly consists of eight identical shore line modules, one for each shore line associated with the attendant's console.

Ship/Shore Control Module (1300 Assembly)

This module contains all the necessary circuitry used to control the operation and interconnection of the ship and shore lines through the attendant's console.

Ring/Busy Interrupter Panel (1400 Assembly)

This panel consists of tone interrupter circuits and a ring timing circuit. It generates ground pulses which control ring voltage and busy tone interruptions used in the selector circuitry.

Ship/Shore Frame Panel (1500 Assembly)

This panel is capable of connecting the eight ship lines to the shore lines, monitoring the ring and busy interrupter circuits, visually indicating that the attendant's console is energized, and providing a direct audio path to the attendant's console for test purposes.

System Power Distribution Panel (1600 Assembly)

This assembly contains two solid-state ring generators, switches for controlling ring voltages, and four major power distribution buses and their associated terminal connectors.

System Connection Panel (1700 Assembly)

Eight terminal blocks are mounted on this panel. They are used as connection points for various system functions.

Battery Charger (1800 Assembly)

The battery charger is a standard, alternating to direct current, solid-state unit of suitable voltage to maintain a 23-, 24-, or 25-cell battery in a fully charged condition.

System Monitor Panel (1900 Assembly)

The system monitor panel is integrated in the MDM system, and can monitor and test all finder/selectors and connectors in the system. The panel contains call count indicators and all-trunks-busy indicators; also, voltage monitoring and alarm locating circuits that give the maintenance man a quick indication to the condition of any switchboard cabinet in the system.

Attendant's Console

The MDM 200/700 installations are equipped with attendant's switching circuitry to provide for attendant-assisted ship-to-shore communications. This circuitry is mounted in the system cabinet, (fig. 10-1) and consists of 8 ship line panels (one for each ship line), 8 shore line panels (one for each shore line), and one control panel. The attendant's switching circuit is controlled from a remotely located attendant's console (fig. 10-3).

Since all of the attendant's switching equipment is mounted in the system cabinet, each console (a maximum of 3 per system) is used only to perform the functions of a standard telephone with pushbutton control of switching modules to seize and interconnect ship lines and shore lines. The consoles are not much larger then standard type-G telephone sets and can be mounted on a desk or bulkhead, or flush mounted in a suitable panel.

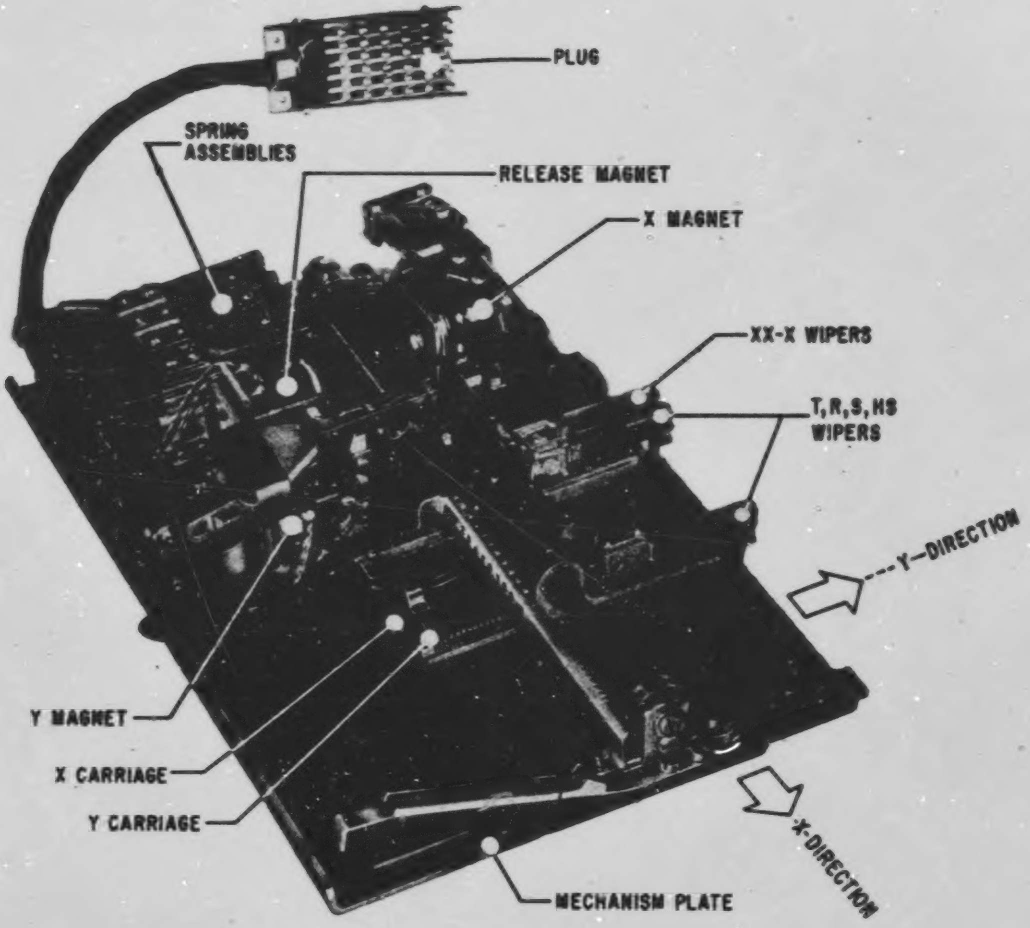
The attendant's console will not be discussed in detail. From the operator's viewpoint, its basic operation is similar to the operation of the Automatic Electric system attendant's cabinet.

SYSTEM OPERATION

This section explains the fundamentals of XY-switching as used in the MDM 200/700 system and describes the operation of the rotary switch that is used as a selector and the operation of the switchboard and control cabinets.

Switching Components and Linefinding

The XY-Universal switch (fig. 10-4) is the heart of the MDM system in that it provides the means for establishing connections throughout the system. The XY-Universal switch is a 100-point, two-motion, remote-control device which may be operated under the control of a dial or automatically pulsed from associated control circuitry. A 100-point, two-motion switch is one that can make electrical contact with any of 100 sets of contacts, taking two motions to accomplish the connection. With the switch mounted in a horizontal plane, the switch carriage moves first in the X-direction, (left to right parallel to the wirebank) and then in the Y-direction (into the wirebank). When mounted in the switchboard, the XY-switch is located adjacent to a 42- by 10-wire matrix, called a wire bank. This wire bank runs the length of the switchboard and serves as the contacts for the wipers of all the XY- switches in the system.



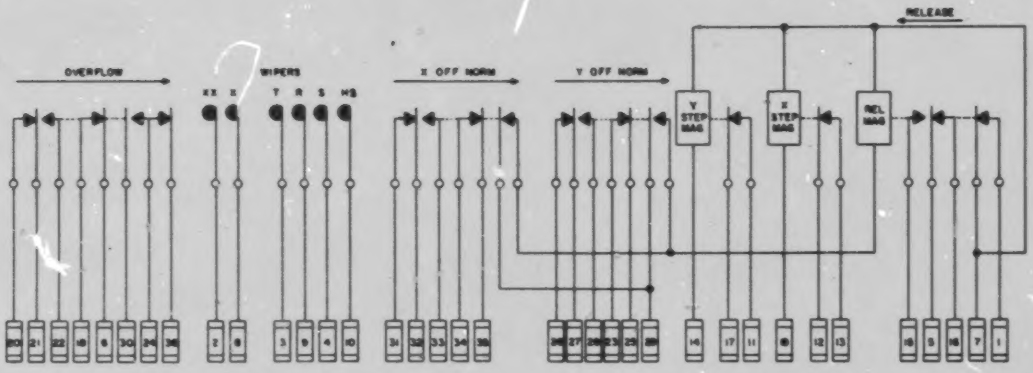
140.165

Figure 10-4.—XY switch.

The XY Switch

The main components of the XY-switch (fig. 10-4) are an X-stepping magnet, a Y-stepping magnet, a release magnet, spring pileups, and associated mechanical drive hardware. A simplified schematic of the XY-switch is shown in figure 10-5. The switch steps first in the X-direction controlled by a series of ground (positive) pulses (periods of current flow) extended to the X-stepping magnet. Each time the magnet operates, the wipers are advanced one step in the X-direction. The Y-stepping magnet functions in a similar manner to drive the wipers in the Y-direction, which is into the wire bank.

The overflow, X-off normal, and Y-off normal spring pileups depend only on the position of the wipers for their operation. The spring position shown in figure 10-5 is the normal position. These springs are used by the associated circuitry to perform various supervisory and control functions. When the wipers are stepped in the X-direction, the X-off normal springs are operated; when stepped in the Y-direction the Y-off normal springs are operated. Only 10 steps are allowed in either direction; if these are exceeded, the overflow springs are operated. When the X-off normal or Y-off normal springs are operated, an operating path is completed to the release magnet. A ground (signal) can then


OVERFLOW
WIPERS
XX
X
T
R
S
HS
X OFF NORM
Y OFF NORM
RELEASE
Y STEP MAG
X STEP MAG
REL MAG
20
21
22
18
6
30
24
36
2
8
3
9
4
10
31
32
33
34
35
26
27
28
23
25
29
14
17
11
12
13
5
16
7
1

140.166

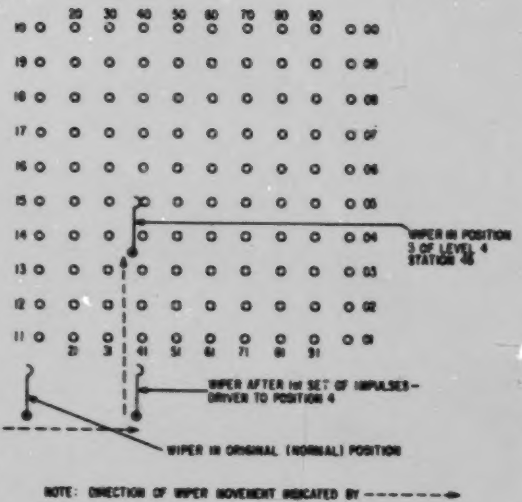
Figure 10-5.—XY universal switch, schematic diagram.

be extended to pin 29 of the XY-switch plug to operate the release magnet, causing the wipers to return to the normal position. The release springs are operated to release the external control circuitry. The release magnet restores when both the X- and Y-off normal springs return to normal.

The Wire Bank

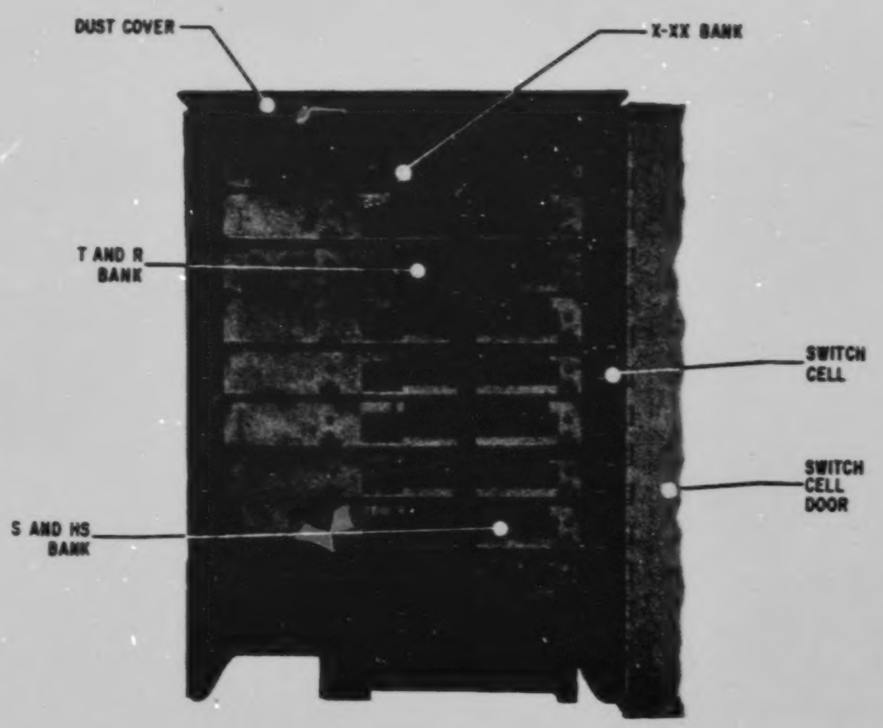
The 42- by 10-wire bank associated with the XY-switch is actually made up of six smaller wire banks: four 10- by 10-wire banks and two 1- by 10-wire banks. The 10- by 10-wire banks are used with the four wires associated with each telephone line. These four wires are the tip (T) and ring (R) for transmission, and sleeve (S) and helping sleeve (HS) for supervisory and switching. The 1- and 10-wire banks (XX and X) are used to electrically indicate the X-position of the wipers when the wipers are stepped in the X-direction. Each of these banks is associated with its own particular wiper on the XY-switch; hence, the switch wipers are referred to as the T, R, S, HS, and XX-X wipers or banks. Figure 10-6 is a simplified diagram of one of the 10- by 10-wire banks (as seen from above) and the associated wiper.

This wire bank runs the length of the switchboard and is associated with the same wiper in all the other XY-switches in the system (fig. 10-6A). The X-motion of the switch locates the wiper at a position (or bank) opposite the proper section of the wire bank. The Y-motion of the switch positions the wiper into the bank to establish the connection at the proper point.


20
30
40
50
60
70
80
90
10
19
18
17
16
15
14
13
12
11
00
09
08
07
06
05
04
03
02
01
21
31
41
51
61
71
81
91
WIPER IN POSITION 5 OF LEVEL 4 STATION 45
WIPER AFTER 1st SET OF IMPULSES—DRIVEN TO POSITION 4
WIPER IN ORIGINAL (NORMAL) POSITION
NOTE: DIRECTION OF WIPER MOVEMENT INDICATED BY

140.167

Figure 10-6.—Wire bank and associated XY switch wiper, simplified schematic diagram.



140.168

Figure 10-6A.—XY switch cell and wire banks.

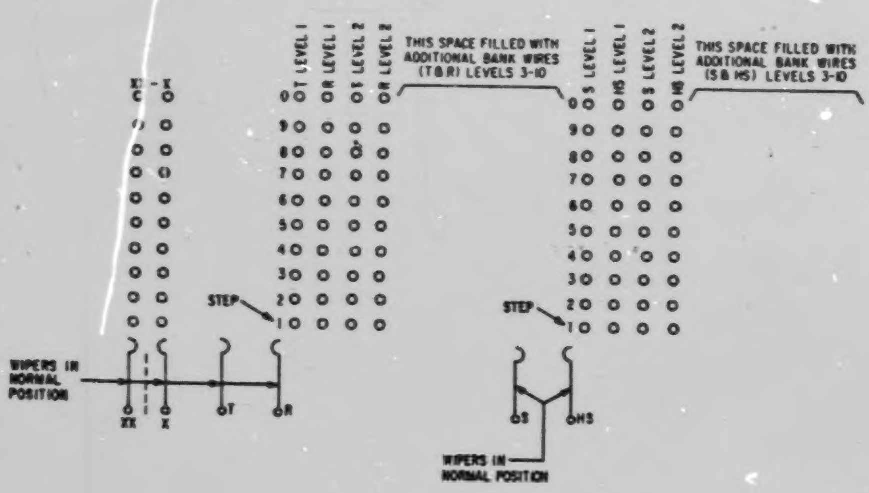
The switch will then remain in position indefinitely until it is released. A terminal block at the end of the wire bank provides the necessary connections to the system circuitry. A simplified schematic diagram of the four 10- by 10-wire banks and the XX-X wire banks is shown in figure 10-7. Figure 10-7A shows the wipers in the normal position. When one wiper of the XY-switch is in a given position in its 10- by 10-wire bank, the other three wipers are in the same position in their respective 10- by 10-wire banks. As the switch steps a certain number of steps in the X-direction (fig. 10-7B), the XX-X wipers advance the same number of steps into the XX-X wire banks. As the switch steps in the Y-direction, the T-, R-, S-, and HS-wipers advance into the wire banks to the desired position (fig. 7-10C).

PRINCIPLES OF LINEFINDING

The basic principles of linefinding in the MDM 200/700 system are similar to those used in the Automatic Electric Strowger system. Both use a certain amount of "shared" equipment since all stations will not be in use all the time. Sharing makes it possible to reduce the number of pieces of switching equipment needed to operate the system. The main pieces of equipment used in linefinding are the line circuit, the linefinder, and the allotter.

Line Circuit

Since the shared equipment must be available on an equal basis to all stations and is not normally connected to any one station, there must be a method of indicating that a particular station requires switching equipment. The line circuit does the indicating by sending a signal to the shared equipment when a station wishes to originate a call. There is one line circuit associated with each station in the system, arranged so that on an incoming call to the station, the shared equipment is not connected with the station.

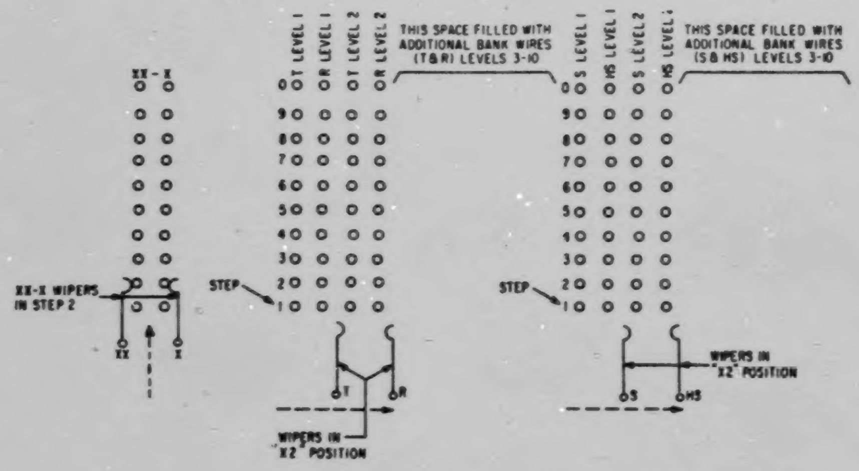

XX - X
T LEVEL 1
R LEVEL 1
T LEVEL 2
R LEVEL 2
THIS SPACE FILLED WITH ADDITIONAL BANK WIRES (T&R) LEVELS 3-10
S LEVEL 1
HS LEVEL 1
S LEVEL 2
HS LEVEL 2
THIS SPACE FILLED WITH ADDITIONAL BANK WIRES (S & HS) LEVELS 3-10
00
90
80
70
60
50
40
30
20
10
STEP
STEP
WIPERS IN NORMAL POSITION
XX
X
T
R
S
HS
WIPERS IN NORMAL POSITION

140.169

Figure 10-7A.—Four wire banks and associated wipers shown in the normal position.

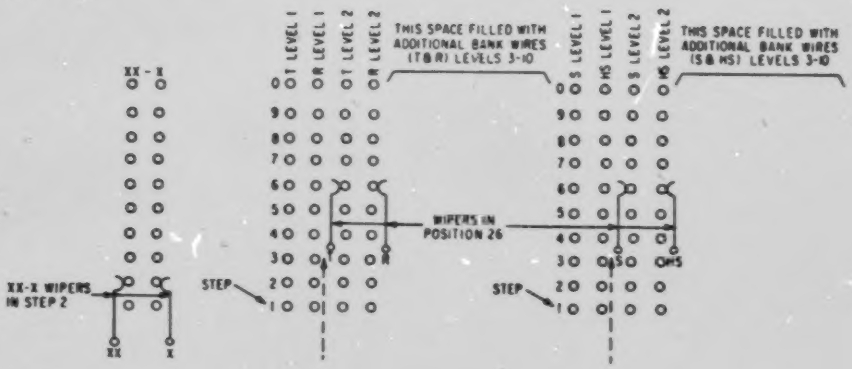
The Linefinder

Figure 10-8 illustrates the basic principles of linefinding. For the sake of simplicity, the allotter is not shown. When the calling party operates his hookswitch by removing the handset from the cradle, the line circuit sends a linefinder start signal to the linefinder. This signal causes the XY-switch to step automatically in the X-direction, searching for the level in the bank where the calling line is located. The XX-X bank and wipers serve to indicate the tens level (level 6 would be the tens level for line 62) of the calling line. When the XY-switch reaches this level, it stops and starts moving into the wire bank in the Y-direction. When


XX - X
T LEVEL 1
R LEVEL 1
T LEVEL 2
R LEVEL 2
THIS SPACE FILLED WITH ADDITIONAL BANK WIRES (T&R) LEVELS 3-10
S LEVEL 1
HS LEVEL 1
S LEVEL 2
HS LEVEL 2
THIS SPACE FILLED WITH ADDITIONAL BANK WIRES (S & HS) LEVELS 3-10
00
90
80
70
60
50
40
30
20
10
XX-X WIPERS IN STEP 2
STEP
STEP
XX
X
T
R
WIPERS IN "X2" POSITION
S
HS
WIPERS IN "X2" POSITION

140.169.1

Figure 10-7B.—Four wire banks and associated wipers shown in the "X2" position.


XX - X
XX-X WIPERS IN STEP 2
XX
X
STEP
0 T LEVEL 1
0 R LEVEL 1
0 T LEVEL 2
0 R LEVEL 2
THIS SPACE FILLED WITH ADDITIONAL BANK WIRES (T & R) LEVELS 3-10
0
9
8
7
6
5
4
3
2
1
T
R
WIPERS IN POSITION 26
S LEVEL 1
HS LEVEL 1
S LEVEL 2
HS LEVEL 2
THIS SPACE FILLED WITH ADDITIONAL BANK WIRES (S & HS) LEVELS 3-10
S
HS
STEP

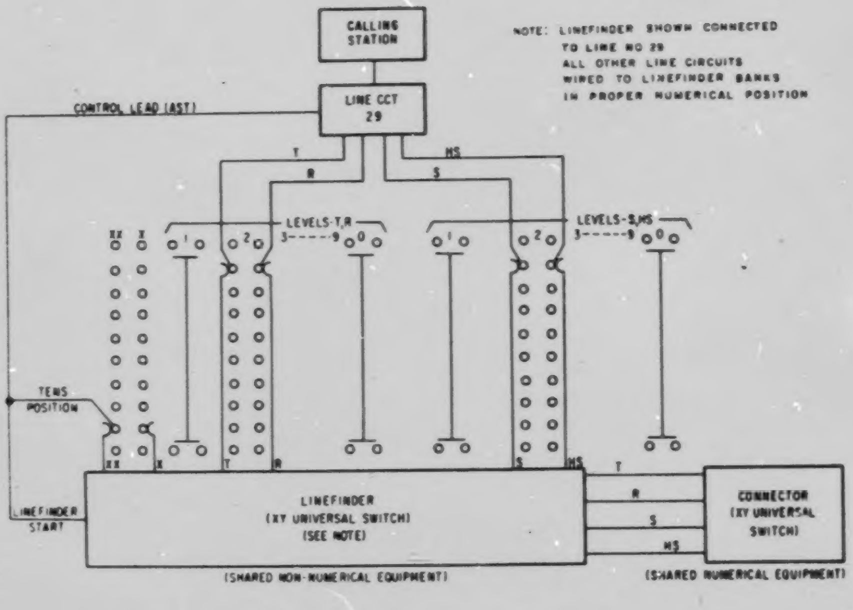
140.169.2

Figure 10-7C.—Four wire banks and associated wipers shown in position 26.

the proper line is located, it stops again and establishes the necessary connections so that the calling station may control the connector with the dial and complete the call. A dial tone then informs the calling party that his line has been found. The linefinder remains connected to the line during the entire call, and is released when the calling party hangs up his handset.

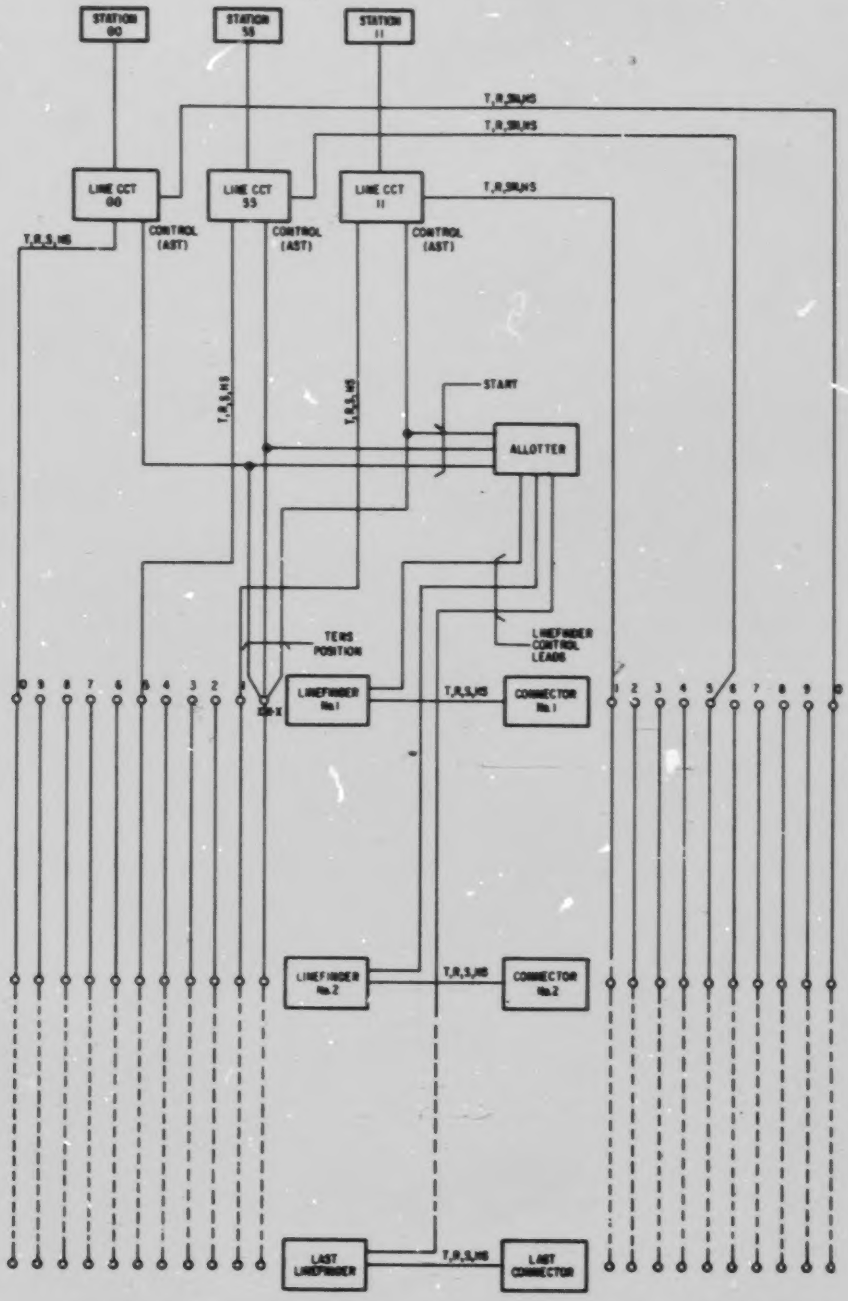
The Allotter

Only one linefinder is shown in figure 10-8. When other calls are made simultaneously from


CALLING STATION
NOTE: LINEFINDER SHOWN CONNECTED TO LINE NO 29
ALL OTHER LINE CIRCUITS WIRED TO LINEFINDER BANKS IN PROPER NUMERICAL POSITION
CONTROL LEAD (AST)
LINE CCT 29
T
R
S
HS
LEVELS-T,R
3-----9
LEVELS-S,HS
3-----9
XX
X
1
2
0
TENS POSITION
LINEFINDER START
LINEFINDER (XY UNIVERSAL SWITCH) (SEE NOTE)
(SHARED NON-NUMERICAL EQUIPMENT)
CONNECTOR (XY UNIVERSAL SWITCH)
(SHARED NUMERICAL EQUIPMENT)

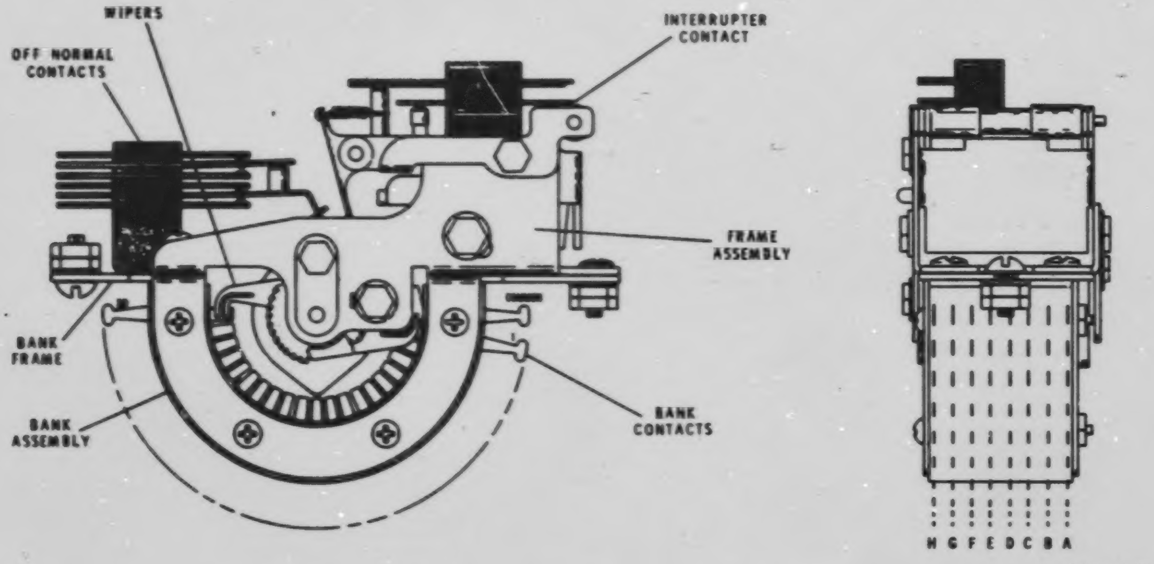
140.170

Figure 10-8.—Block diagram of linefinder operation.


STATION 00
STATION 55
STATION 11
T,R,SN,HS
T,R,SN,HS
LINE CCT 00
LINE CCT 55
LINE CCT 11
T,R,SN,HS
T,R,S,HS
CONTROL (AST)
CONTROL (AST)
CONTROL (AST)
T,R,S,HS
T,R,S,HS
START
ALLOTTER
TENS POSITION
LINEFINDER CONTROL LEADS
10
9
8
7
6
5
4
3
2
1
10-X
LINEFINDER No.1
T,R,S,HS
CONNECTOR No.1
1
2
3
4
5
6
7
8
9
10
LINEFINDER No.2
T,R,S,HS
CONNECTOR No.2
LAST LINEFINDER
T,R,S,HS
LAST CONNECTOR

140.171

Figure 10-9.—100 line XY system using shared equipment.



140.172

Figure 10-10.—Rotary stepping switch, selector.

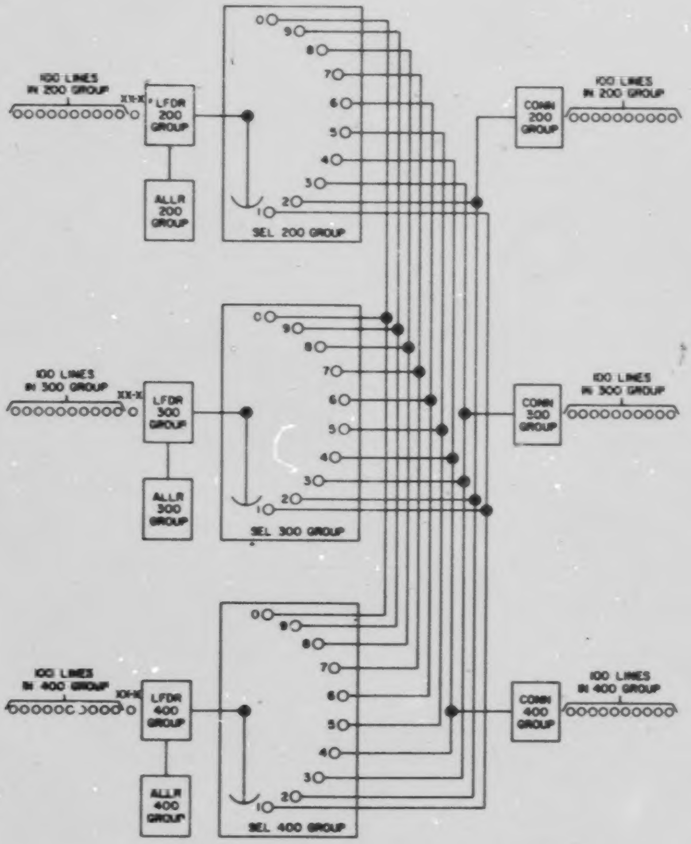
other stations, additional linefinders must be available. The function of the allotter (fig. 10-9) is to assign linefinders to any of the line circuits as required. When any line requests service, the allotter assigns a linefinder to the call, then pre-selects the next idle linefinder to be assigned to the next call. As busy linefinders become idle, they are made available for allottment to any subsequent calls. When one XY-switch is connected to a given position in the wire bank, no other XY-switch in the system may connect to that position. The S-lead of the telephone and the S-wire bank are used to indicate the busy condition. For example, if station 55 calls station 21, a busy indicator, called mark, is immediately extended to position 55 of the S-wire bank from the station 55-line circuit. After the associated connector XY-switch has been stepped to position 21 of the wire bank (under the control of dial pulses from station 55), a busy mark is applied to that position in the S-wire bank from the connector. If any other station, say station 78, now tries to call station 55 or 21, the associated connector XY-switch will encounter the busy mark and send a busy signal to the calling party (station 78).

The Selector

The selector in the MDM 200/700 system performs the same basic function as the selector in the Automatic Electric system. Connected back to back with a finder, the selector locates an idle connector in the group of lines (switchboard) to which a call is being made.

The MDM 200/700 system uses a 20-point, 8-level, rotary switch as a selector (fig. 10-10). This switch may be stepped by pulses from the dial or be operated in an automatic hunt sequence by use of interrupter spring contacts. The rotary switch wiper moves after it has been released electronically; that is, when the step magnet is operated the wipers do not go into the next position until the step magnet is released. In a typical commercial XY-installation the rotary switch is used with the allotter circuits. However, in the Marine Dialmaster, the rotary switch is used in the selector circuits.

A typical MDM system having 300 telephone stations, in three groups (switchboards) of 100 each, is represented by the block diagram of figure 10-11. One finder/selector, one allotter, and one connector represents each switchboard.


100 LINES IN 200 GROUP
XX-X
LFDR 200 GROUP
ALLR 200 GROUP
0
9
8
7
6
5
4
3
2
1
SEL 200 GROUP
CONN 200 GROUP
100 LINES IN 200 GROUP
100 LINES IN 300 GROUP
XX-X
LFDR 300 GROUP
ALLR 300 GROUP
SEL 300 GROUP
CONN 300 GROUP
100 LINES IN 300 GROUP
100 LINES IN 400 GROUP
XX-X
LFDR 400 GROUP
ALLR 400 GROUP
SEL 400 GROUP
CONN 400 GROUP
100 LINES IN 400 GROUP

140.173

Figure 10-11.—The rotary switch in the selector, simplified block diagram.

Each selector terminates into a connector circuit. The selector (using a rotary switch) is the link between the linefinder and the connector. Although the rotary switch has 20 positions, only 10 are shown.

SAMPLE CALL

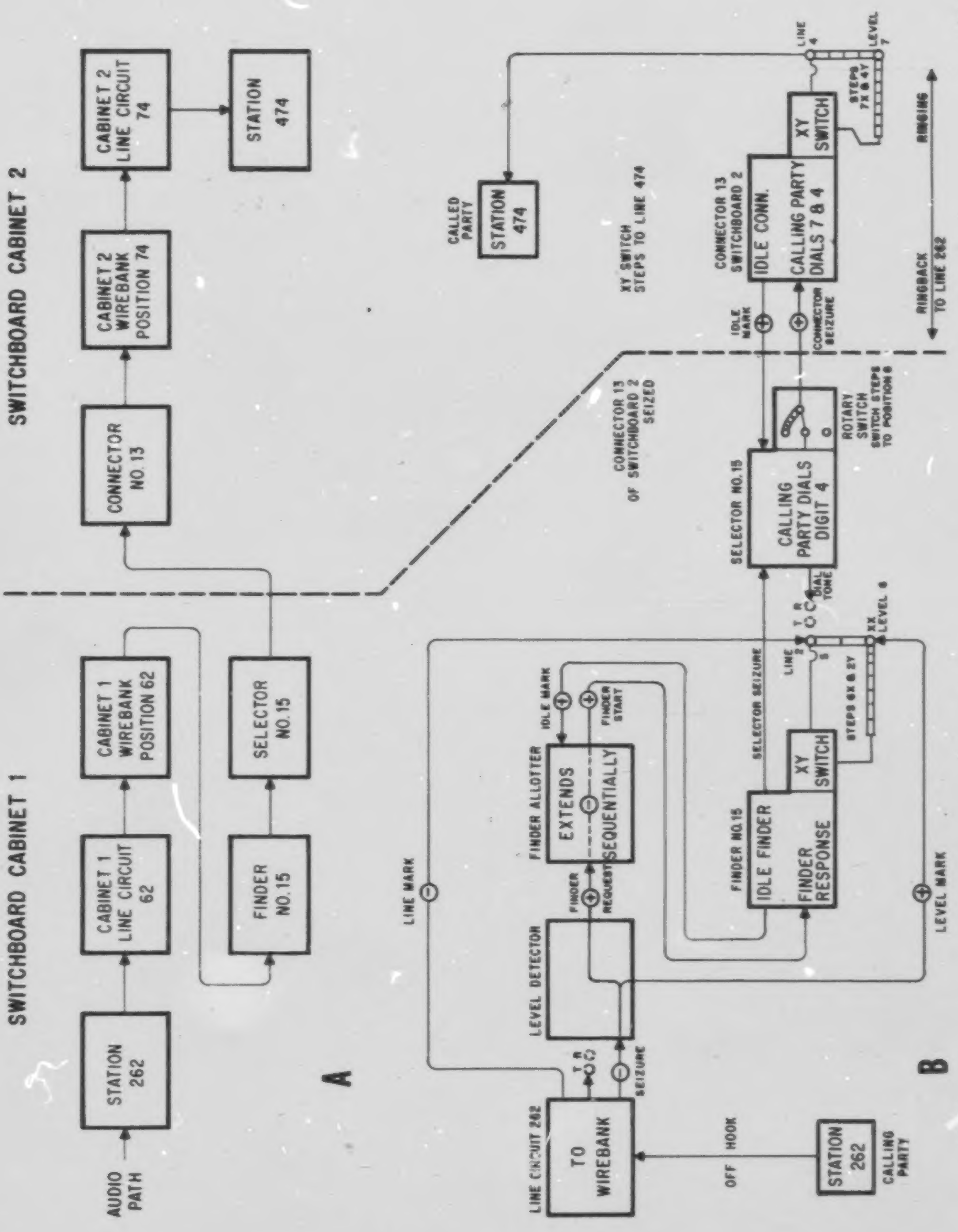
Figure 10-12 is a simplified block diagram tracing a sample call from one station to another. As an aid toward understanding the actions involved in completing this call, keep in mind the following facts concerning the MDM system:

A. Each telephone station has audio (tip and ring) leads which terminate in the wire bank of a switchboard cabinet.

B. A calling station initiates finder action by removing the handset from the cradle, causing shared switching equipment to be placed under the control of the calling line by way of a connection in the wire bank.

C. Dialing from the calling station extends the switching link to a wire bank position which terminates the audio leads of the called station.

The sample call diagrammed in figure 10-12 is between station 262 (the calling party) and station


SWITCHBOARD CABINET 1
SWITCHBOARD CABINET 2
AUDIO PATH
STATION 262
CABINET 1 LINE CIRCUIT 62
CABINET 1 WIREBANK POSITION 62
FINDER NO.15
SELECTOR NO.15
CONNECTOR NO.13
CABINET 2 WIREBANK POSITION 74
CABINET 2 LINE CIRCUIT 74
STATION 474
A
LINE CIRCUIT 262
TO WIREBANK
T R
SEIZURE
OFF HOOK
STATION 262
CALLING PARTY
LINE MARK
LEVEL DETECTOR
FINDER REQUEST
FINDER ALLOTTER
EXTENDS
SEQUENTIALLY
IDLE MARK
FINDER START
FINDER NO.15
IDLE FINDER
FINDER RESPONSE
XY SWITCH
LEVEL MARK
SELECTOR SEIZURE
STEPS 6X & 2Y
LINE 2
XX LEVEL 6
DIAL TONE
SELECTOR NO.15
CALLING PARTY DIALS DIGIT 4
ROTARY SWITCH
SWITCH STEPS TO POSITION 8
CONNECTOR 13 OF SWITCHBOARD 2 SEIZED
IDLE MARK
CONNECTOR SEIZURE
CONNECTOR 13 SWITCHBOARD 2
IDLE CONN.
CALLING PARTY DIALS 7 & 4
XY SWITCH
STEPS 7X & 4Y
LINE 4
LEVEL 7
XY SWITCH STEPS TO LINE 474
CALLED PARTY
STATION 474
RINGBACK TO LINE 262
RINGING
B

140.174

Figure 10-12.—Sample call audio path and switch control path.

474 (the called party). Assume that station 474 is not busy at the time of the call and that the idle connector is connector No. 13 in the switchboard of the called station.

The T- and R-leads for line 262 terminate in switchboard cabinet No. 1 and extend to wire bank position 62 by way of the line circuit serving level 6, line 2. When the calling party operates the hook switch, line circuit 262 extends two sources of battery (negative signal voltage), one to the S-wire bank position for line 62 for Y-direction hunt stop, and the other to seize the 6-section of the level detector. The level detector responds to level 6 seizure by extending level mark ground to mark position six of the XX-wire bank for X-direction hunt stop, and request ground to the finder allotter.

The finder allotter, which serves to allot idle finders, routes the request ground to the next available finder in the allotter sequence. Assume that finder No. 15 is the next one available. This finder responds to automatically hunt for the calling line in the wire bank by stepping its associated XY-switch in the X-direction until the XX-wiper encounters the level mark ground in the XX-wire bank. The X-direction hunting then stops and Y-direction hunting automatically begins. After two steps, the S-wiper encounters the line mark battery which halts the Y-direction hunting. The finder XY-switch wipers now rest in the wire bank position of the calling line 262.

As soon as line 262 is found, finder No. 15 seizes its associated selector (No. 15) and dial tone is returned to the calling station by way of the wire bank connection. The calling party now dials the initial digit 4 of the called station (474) and the rotary switch associated with selector No. 15 steps to seize the next idle connector in switchboard No. 2. The next idle connector in this case was connector No. 13. Selector No. 15 extends a seizure ground which prepares the connector circuitry for the second and third digits to be dialed. When the calling party dials digit 7, the wipers of the XY-switch associated with connector No. 13 step seven times in the X-direction, following the dial pulse. When the digit 4 is dialed, the wipers step four times in the Y-direction. The XY-switch wipers now rest on the wire bank position corresponding to called line 474. The connector extends ring voltage from the selector to the called line. When the called party answers, the switch-through is completed. The audio path for the call is shown in part B of figure 10-12.

CHAPTER 11

SOUND RECORDING AND REPRODUCING SYSTEMS

Sound recording and reproducing systems are used on board ship and at shore stations to monitor radio and soundpowered telephone circuits for short-memory and permanent-record applications and to record signals for future analysis for instrumentation applications. They are used also to train, entertain, and provide religious services for personnel and for office functions, such as dictation, conference, and telephone recording.

This chapter describes techniques of recording and reproducing sound, characteristics and operating principles of a typical record player, the AN/UNQ-7E sound tape recorder-reproducer set, and a representative commercial tape deck. Also included are general instructions on how to operate and maintain a tape recorder.

SOUND RECORDING AND REPRODUCING TECHNIQUES

The basic techniques of recording and reproducing sound are (1) mechanical, (2) photographic, and (3) magnetic. The recording medium is a disk, film, tape, or wire; it is usually determined by the recording technique.

Disk, film and wire mediums are becoming obsolete due to the superiority of tape mediums.

MECHANICAL TECHNIQUE

In the mechanical recording technique, the material is mechanically cut (engraved) or deformed (embossed) as it is driven past a stylus, or cutting needle, to form a spiral groove in the recording material and thus preserve the pattern of the sound. The sound pattern can be engraved on disks and embossed on disks or films. Embossed disks are rarely used in the Navy today, except for some dictation equipments.

The components necessary to mechanically record sound are (1) a microphone, (2) an audio amplifier, (3) a recording head, (4) a stylus, and (5) a recording medium, usually a vinyl disk. The microphone converts the sound waves produced by the voice into corresponding electrical signals that are applied to the amplifier. The output of the amplifier is fed to the recording head, which converts the electrical signals into mechanical energy causing a lateral movement of the stylus. The stylus either engraves or embosses the recording medium as it moves from side to side.

The components necessary to play back a disk recording are: (1) a playback head, (2) a stylus, (3) an audio amplifier, and (4) a loudspeaker. When a disk recording is played back, the disk is rotated at the same speed as that at which the recording is made. The playing stylus, or needle, rests in the groove and follows the pattern of the sound groove. The playback head into which the stylus is mounted converts the mechanical movements into corresponding electrical signals, which are applied to the audio amplifier. The output of the audio amplifier is fed to a loudspeaker, which converts the electrical signals into corresponding audio signals.

PHOTOGRAPHIC TECHNIQUE

In the photographic recording technique, the sound is recorded by exposing a moving photosensitive film to a beam of light, which is modulated by the sound pattern being recorded. When the film is developed, it can be reproduced by passing the sound track, which contains the light and dark areas, through a beam of light focused on a photoelectric cell. The output of the cell is fed to an audio amplifier, and then to a loudspeaker, which reproduces the electrical signals into sound waves. The methods of recording sound photographically are (1) variable area and (2) variable density recording.

Variable Area Recording

In variable area recording, the sound pattern is recorded by a small mirror mounted on a

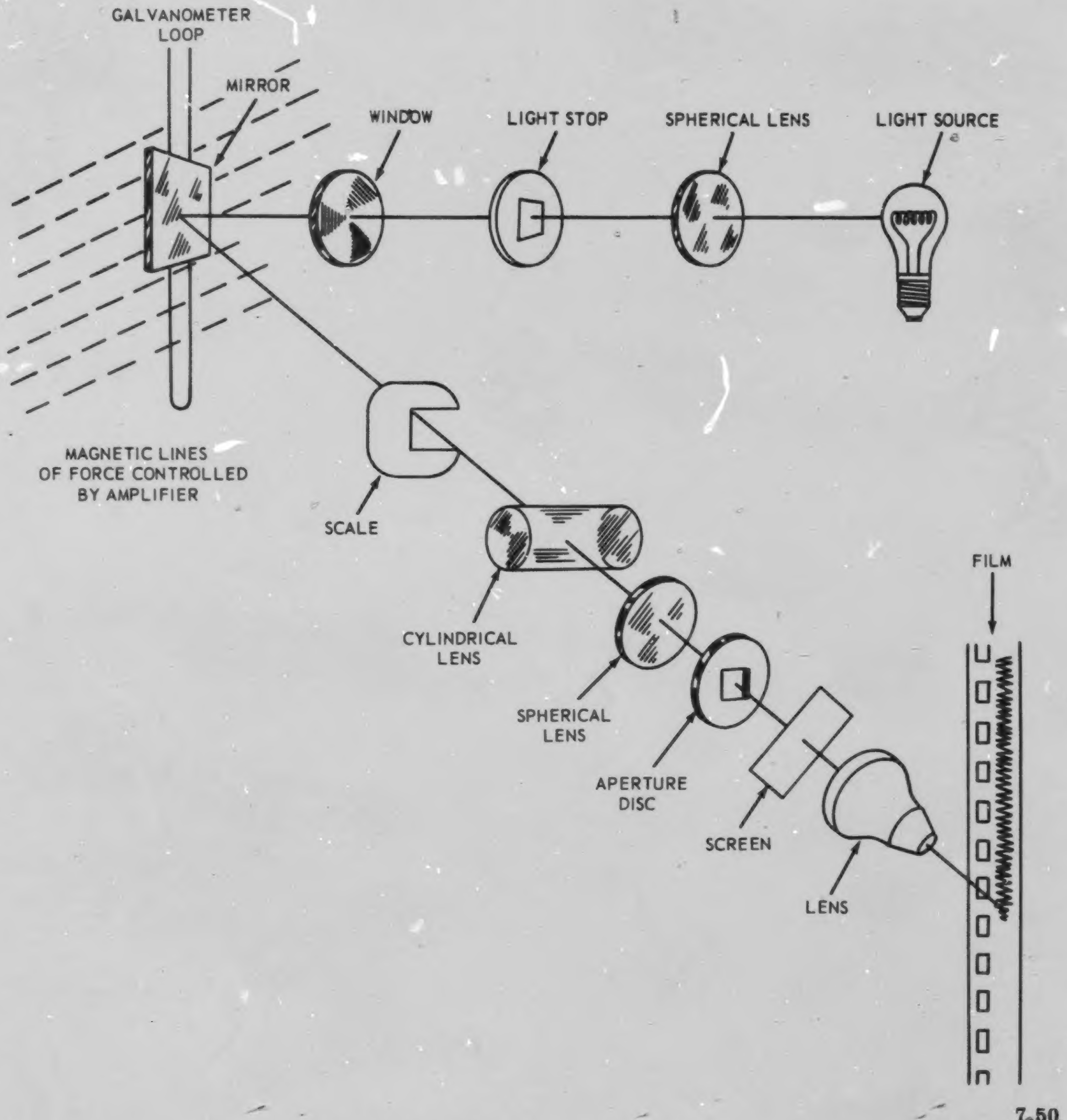

GALVANOMETER LOOP
MIRROR
WINDOW
LIGHT STOP
SPHERICAL LENS
LIGHT SOURCE
MAGNETIC LINES OF FORCE CONTROLLED BY AMPLIFIER
SCALE
CYLINDRICAL LENS
SPHERICAL LENS
APERTURE DISC
SCREEN
LENS
FILM
7.50

Figure 11-1.—Variable area recording.

sensitive galvanometer. The modulated current produced by the sound vibrations on the microphone is amplified and fed to a sensitive galvanometer consisting of a fine loop of wire. A small mirror is attached to this loop and the loop is suspended in a magnetic field (fig. 11-1). A beam of light from a high intensity lamp passes through a condenser lens and is focused on the galvanometer mirror from which it is reflected through another condenser lens to a slit or aperture. The resulting slit of light passes through a projector lens onto the film. When current flows through the galvanometer, the wire loop is set in vibration, carrying the mirror with it to trace a line of light not to exceed the width of the slit across the sound track of the film. This type of sound track has a constant density and a varying width along one edge of the film.

Variable Density Recording

In variable density recording, the sound pattern is recorded by varying the densities of the image, which is produced by light passing through a special type of light valve, as shown in figure 11-2A. The light valve consists of a Duraluminum ribbon loop, suspended between the two pole pieces of a powerful electromagnet. The two halves of the ribbon loop are connected to a recording amplifier. The loop opens and closes in response to the input signals to allow varying amounts of light to expose the film as shown in figure 11-2 B and C. This type of sound track has a varying density and a constant width along one edge of the film.

MAGNETIC TECHNIQUE

In the magnetic recording technique, a permanent magnetic material is magnetized in accordance with the pattern of the sound, as the recording medium is driven past a recording head. Similar to mechanical recording, the sound waves are picked up by a microphone, converted to corresponding electrical signals, and amplified. Unlike mechanical recording, the amplified electrical signals are applied to the recording head, which orients the magnetic particles in the tape or wire.

The recording head consists of coils wound on an iron core similar to an electromagnet. During one-half cycle, the signal current flows through the coils in one direction. The iron core becomes magnetized, and establishes a north and a south pole at the ends of the U-shaped electromagnet. A magnet field exists in the air gap between the poles. When the direction of the current through the coils is reversed, the direction of the lines of force across the air gap is reversed. If a magnetic wire is placed across the gap of the magnet, most of the lines of force would be confined within the wire, and it would become magnetized.

Tape Recording

In magnetic tape recording, a flat, polyester coated, plastic tape is used as the recording medium (fig. 11-3A). The magnetic fields that comprise the sound pattern are established on the tape, which is coated with very fine steel particles (fig. 11-3A). The recording head and its air gap (fig. 11-3B) comprise a series magnetic circuit. The principle involved is the same as that for wire recording, but tape recording has the advantage of being easier to handle and less expensive.

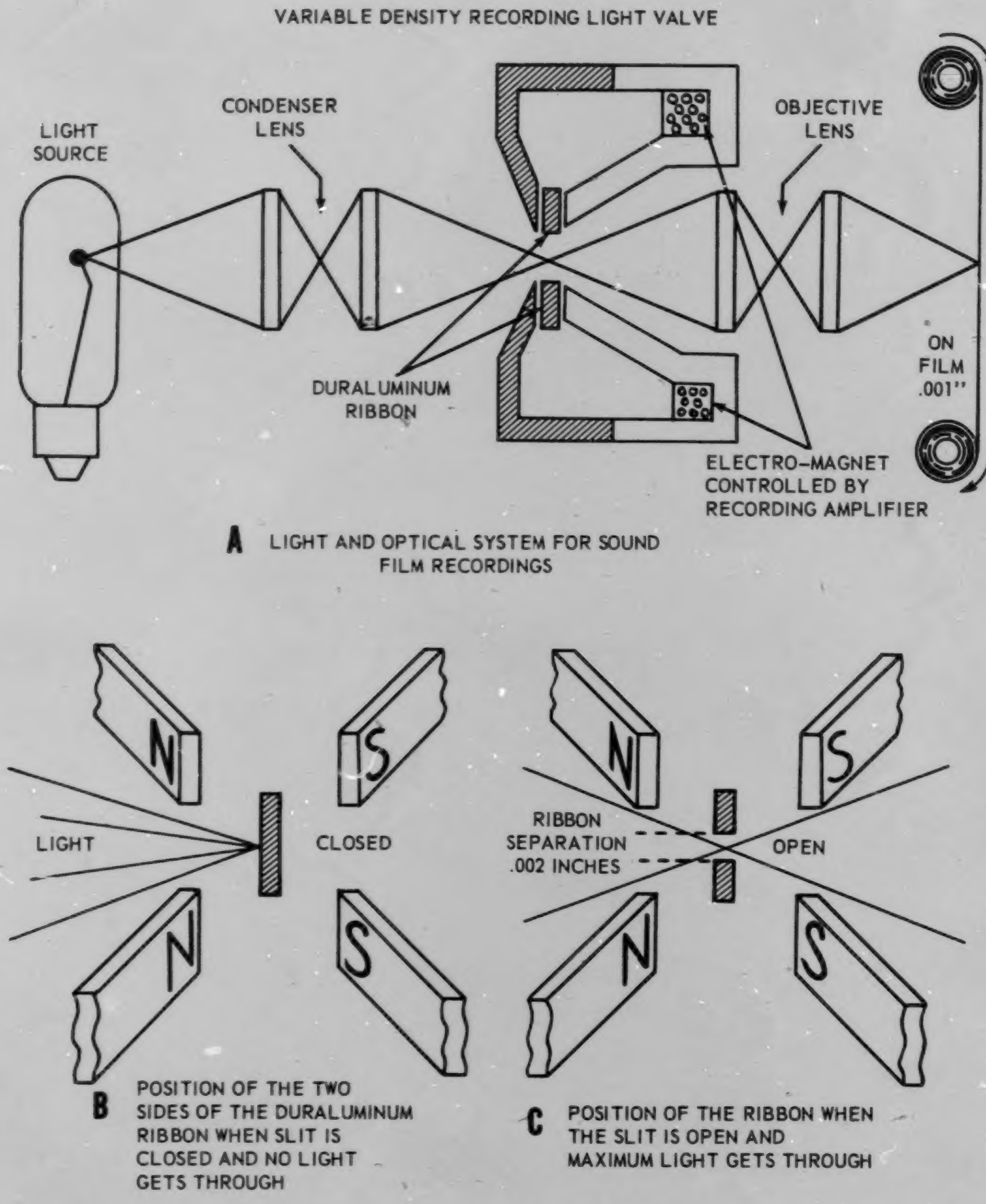
A-C Biasing

In most magnetic recording, an a-c bias is used on which the audio signal is superimposed and applied to the recording head. This bias is a relatively high-frequency, a-c signal, that is above the audio range, and therefore cannot be heard during playback. A-c biasing is used to obtain a substantially linear relationship between the flux density in the recording medium and the magnetizing force. Thus, the induced signal voltages are related linearly to the recording fields.

The magnetization curve (heavy line) of the iron oxide used as the recording medium is similar to that shown in figure 11-3C. At points near the origin the curve is nonlinear, and without some corrective factor, the signal recorded on the tape would not be directly proportional to the signal applied to the recording head. This condition would cause distortion when the tape was played back.

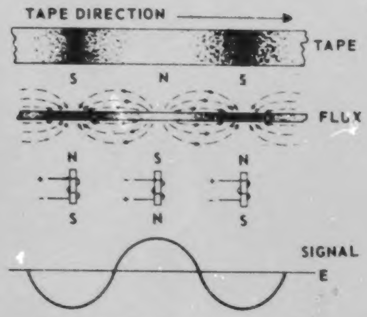
The distortion is greatly reduced by mixing a high-frequency, constant-amplitude signal with the audio signal. The a-c bias is placed in series with the audio signal. This connection causes the average bias to be shifted in a positive direction on the positive alternations of the audio signal and in a negative direction on the negative alternations of audio signal. If the audio signal being recorded is of sine waveform, the flux pattern will be of sine waveform. The waveform is developed from the vertical to horizontal projections obtained from the magnetization (transfer) curve shown in figure 11-3C.

While the tape is in the recording gap the a-c bias causes the magnetization of the iron oxide to follow the dashed line loops (minor hysteresis loops). As the tape leaves the gap the influence of the mmf is reduced to zero and the degree of magnetization existing at that time

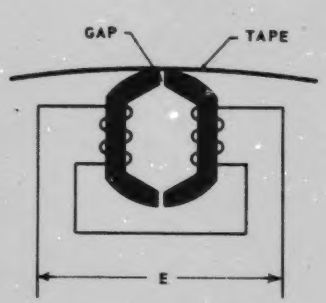

VARIABLE DENSITY RECORDING LIGHT VALVE
LIGHT SOURCE
CONDENSER LENS
OBJECTIVE LENS
DURALUMINUM RIBBON
ON FILM .001''
ELECTRO-MAGNET CONTROLLED BY RECORDING AMPLIFIER
A LIGHT AND OPTICAL SYSTEM FOR SOUND FILM RECORDINGS
N
S
N
S
LIGHT
CLOSED
RIBBON SEPARATION .002 INCHES
OPEN
N
S
N
S
B POSITION OF THE TWO SIDES OF THE DURALUMINUM RIBBON WHEN SLIT IS CLOSED AND NO LIGHT GETS THROUGH
C POSITION OF THE RIBBON WHEN THE SLIT IS OPEN AND MAXIMUM LIGHT GETS THROUGH

7.51

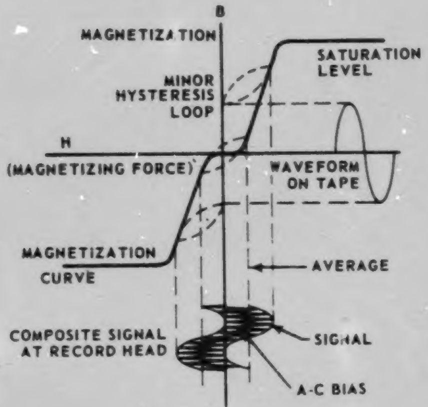
Figure 11-2.—Variable density recording.



A - TAPE MAGNETIZATION



B - RECORDING HEAD



C- A-C BIASING

7.53

Figure 11-3.—Tape recording.

depends on the remnant magnetism or that remaining when the magnetizing force is removed.

After the recording process, the flux pattern on the tape is proportional in magnitude and direction to the signal being recorded. If the tape is then moved past a reproduce head that is like the record head, the flux on the tape will induce a voltage in the coil of the reproduce head. This voltage comprises the audio signal.

Notice that the a-c bias keeps the remnant flux sufficiently removed from the origin (zero magnetization with zero magnetizing force) to prevent distortion of the audio signal. The flux pattern established by the a-c bias 100,000 Hz is of sufficiently high frequency not to be heard.

Erasing

The recording sound track on a magnetic recording medium can be erased (by a special erase head) and the medium used again for further recording. The erase head is located so that the wire or tape must pass through it before reaching the recording head. A high-frequency a-c signal is fed to the erase head and thus cancels the magnetic fields from a previous recording by completely disorienting the magnetic particles in the wire or tape.

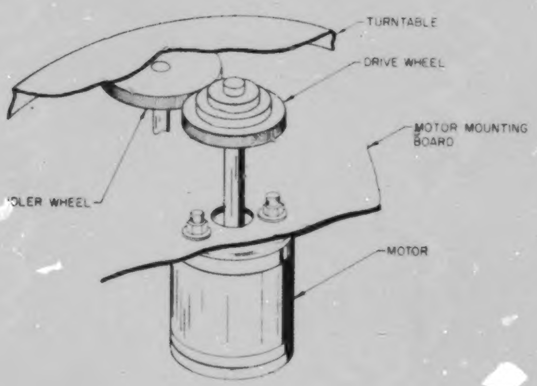
RECORD PLAYERS

The main elements of a record player are the cartridge, turntable, and tone arm. An amplifier and speaker may also be included, but in most instances will be separate. The turntable may come equipped with a record changer which will permit the loading of as many as a dozen records at one time. Every Navy record player does not have a record changer, which is usually a feature of civilian equipment acquired through open purchase. Today's record players offer a choice of four speeds: 16 2/3, 33 1/3, 45, and 78 rpm.

CARTRIDGES

The phonograph cartridge, or pickup, is used to convert variations in the grooves of a phonograph record into corresponding electrical signals. Phonograph cartridges can be divided into two types: (1) ceramic or crystal cartridges and (2) magnetic cartridges. Each type of cartridge is either monophonic for monaural records or stereophonic for stereo records.

The crystal cartridge was used extensively on early record players but is rarely found in modern record players. The ceramic cartridge, having replaced the crystal, is the most common of those used in Navy record players. However, those purchased on the open market usually have magnetic cartridges which are capable of better reproduction than the ceramic cartridges.



140.133
Figure 11-4. — Turntable drive system.

TURNTABLES

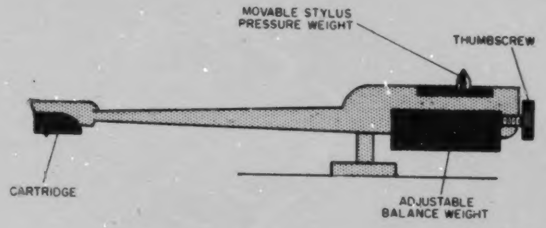
The turntable of a record player is simply a rotating platform, on which one or more records are placed for playback. This platform is driven by a motor or some form of drive system. There are two types of turntables: the single record player that requires manual record changing and the automatic record changer.

Most turntables are driven by a constant speed motor through a drive system consisting of a drive wheel and an idler wheel. The drive wheel is either uniform or stepped. The stepped drive wheel (fig. 11-4) is used in multispeed turntables with each step corresponding to a different speed. The idler wheel is used to reduce rumble or uneven motion of the turntable.

When the largest step of the drive wheel is in contact with the idler wheel, the turntable will turn at its maximum speed; when the smallest step is in contact with the idler wheel, the turntable will turn at its lowest speed. In this way, a 4-step wheel can drive the turntable at its different speeds: 16 2/3, 33 1/3, 45, and 78 rpm. Various methods of shifting from one speed to another exist, but most manufacturers use a spring-loaded cam or similar device.

TONE ARMS

The tone arm of a record player is used to hold the cartridge and carry it into position over the record. When used with an automatic record changer, the tone arm is moved out of the way of the record as it drops into place, then moves to the start position over the record, and drops slowly until the pickup touches the record. In the single-record player, the tone arm is lifted by hand to the start position over the record and then lowered into place. Care must be taken so as not to damage either the cartridge or the record.



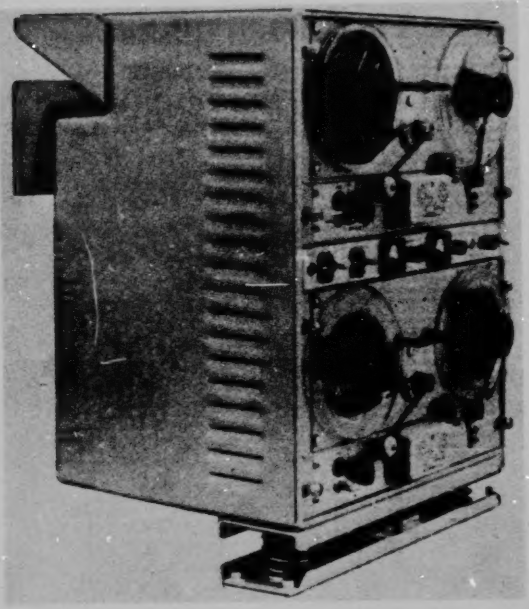
140.134
Figure 11-5. — Tone arm.

The tone arm used in a high fidelity or stereo system has several balances or adjustments which are critical to the sound reproduction of the system. These adjustments concern the lateral and vertical movements of the tone arm and also static and dynamic balancing of the arm. Do not try any of these adjustments unless you have a complete list of the manufacturer's specifications for your system. Figure 11-5 shows a typical tone arm that has two movable weights for balancing the arm.

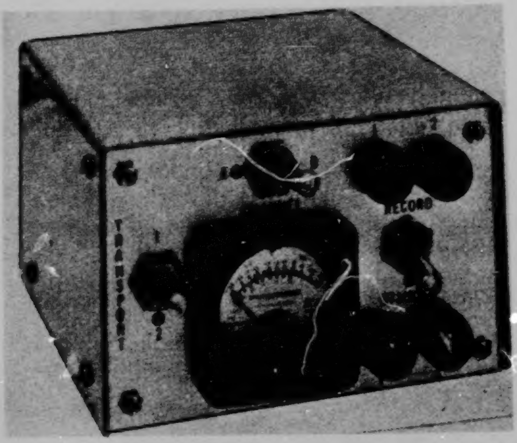
SOUND RECORDER-REPRODUCER SET AN/UNQ-7E

The AN/UNQ-7E is designed as a dual tape transport to record and reproduce audio frequencies on standard 1/4-inch magnetic recording tape. It consists of two major assemblies: the equipment cabinet which houses two recorder-reproducers (tape transports No. 1 and 2) and the remote control unit (RCU). See figures 11-6 and 11-7. The numbers, 1 and 2, associated with the tape transports refer to the upper and lower transports, respectively.

Electrical signals falling within the normal audio frequency spectrum can be recorded at tape speeds of 3.75, 7.5, or 15 inches per second (ips). Only one tape transport at a time can record. Information that was previously recorded on one transport can be played back at the same time other information is being recorded on



7.54(140B)A
Figure 11-6.—Recorder-reproducer.



7.40(140B)
Figure 11-7.—Remote control unit.

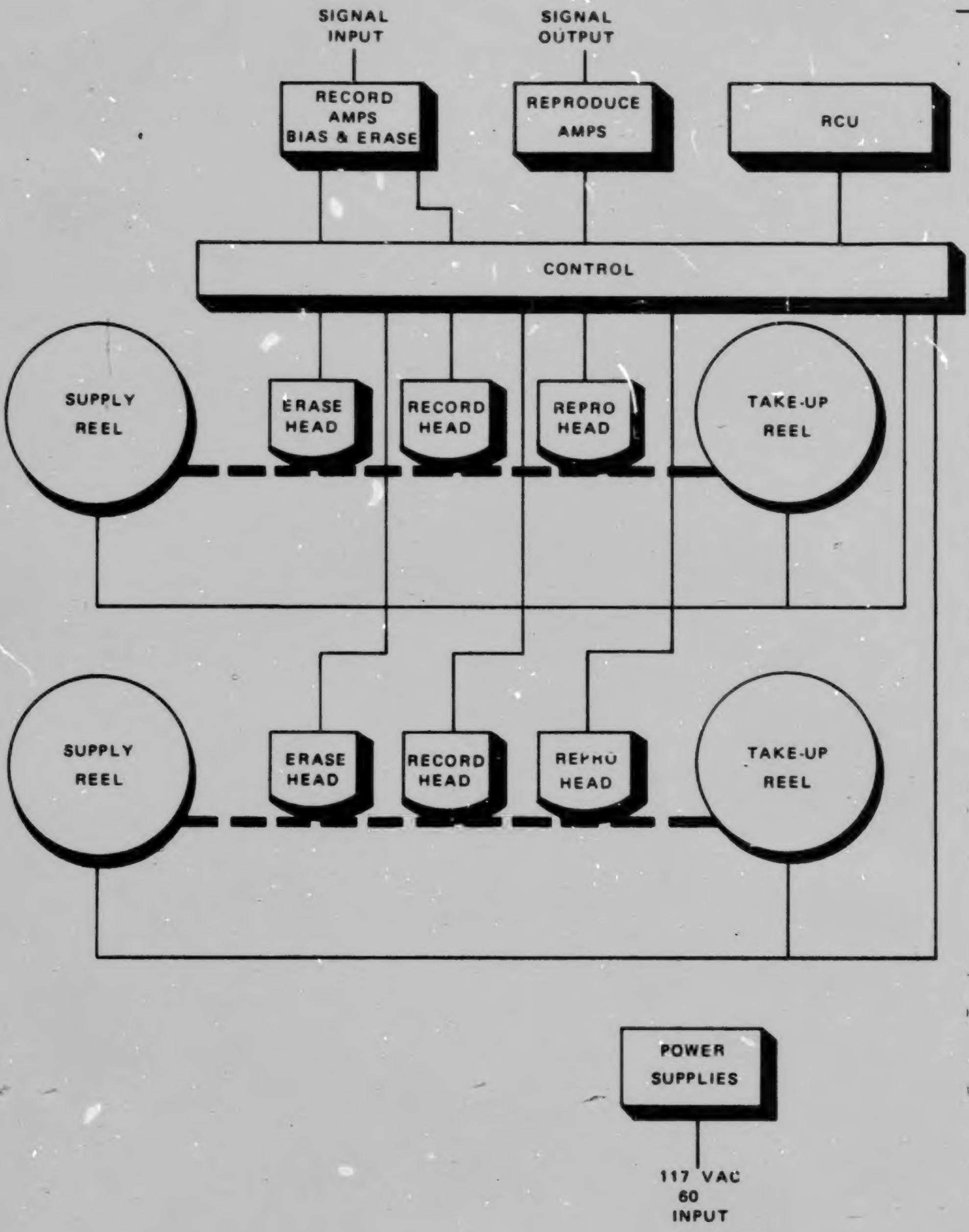
the second transport. There are two channels—one for voice recording (channel A) and the other for data information (channel B). Figure 11-8 is a functional block diagram of this recorder-reproducer.

The tape is first contacted by the erase head which removes any previously recorded signal. It is then contacted by the record head which magnetizes the tape in proportion to the audio signal. When operating in the reproduce mode the tape contacts a reproduce head which senses the fluctuations in magnetic field strength and converts them into electrical signals. These signals are then amplified by the reproduce amplifier. The control section selects the transport, controls movement of the tape, and selects the amplifier section. The remote control unit functions are limited to record and stop. The power supplies provide the proper level and amount of regulation required by each group of circuits.

EQUIPMENT CABINET

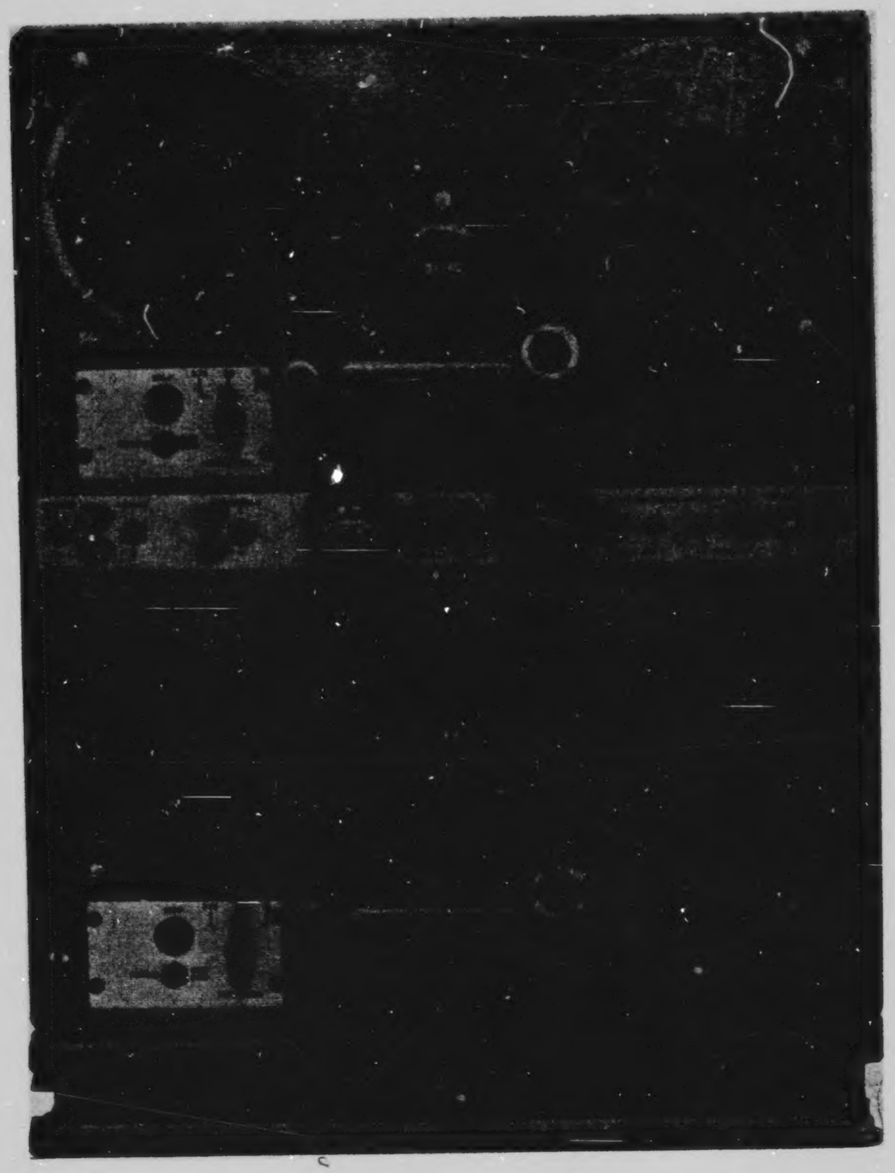
The electrical equipment cabinet (fig. 11-9) contains the two tape transports (fig. 11-10) and the following electronic assemblies: a channel A and B record preamplifier, a channel A and B reproduce amplifier, a bias and erase oscillator, and an a-c power supply. With the exception of parts of the power supply and the power amplifiers, these assemblies are self-contained modular components which plug into rack-mounted receptacles within the cabinet.

The record preamplifier incorporates a manually operated automatic gain control (AGC) defeat switch for disabling the channel B AGC circuit during certain recording applications. All functions of the recorder-reproducer set, with the exception of the channel B bias defeat and AGC defeat, can be controlled from the front of the equipment cabinet. A two-position toggle switch is used to turn the power off and on. All other function control switches on the front of the cabinet are three-position, center off, momentary contact toggle switches. One tape transport can record while the other reproduces pre-recorded data, and one can record or reproduce while the other is in either the fast forward on rewind mode of operation. The controls also facilitate any combination of simultaneous fast forward and rewind operation of the two tape transports. A three-position, rotary speed selection switch, a momentary, push-action stop button, and a fast-forward-rewind toggle switch are located just below the supply reel on each transport. Also located on the front of the cabinet are the channel A and B record level VU meters and record level controls, channel A and B output jacks and output level controls, record and


SIGNAL INPUT
SIGNAL OUTPUT
RECORD AMPS BIAS & ERASE
REPRODUCE AMPS
RCU
CONTROL
SUPPLY REEL
ERASE HEAD
RECORD HEAD
REPRO HEAD
TAKE-UP REEL
SUPPLY REEL
ERASE HEAD
RECORD HEAD
REPRO HEAD
TAKE-UP REEL
POWER SUPPLIES
117 VAC 60 INPUT

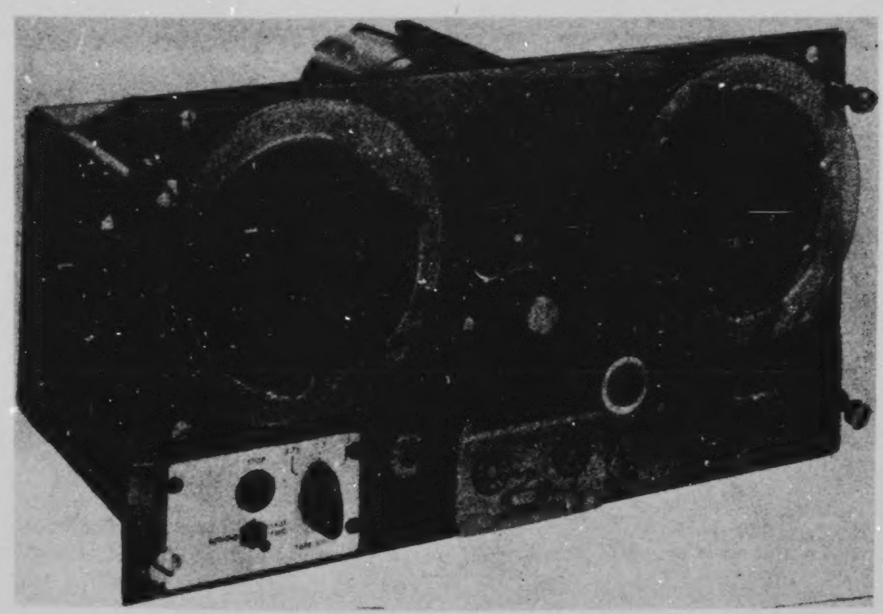
140.135

Figure 11-8.—Recorder-reproducer overall functional block diagram.



7.54(140B)B

Figure 11-9.—Operating controls, recorder-reproducer.



7.54(140B)C

Figure 11-10.—Recorder-reproducer, magnetic (tape transports).

reproduce indicator lights for tape transports 1 and 2, and a power on indicator light. All indicator lights have mechanical dimmer mechanisms.

REMOTE CONTROL UNIT

The remote control unit (fig. 11-7) permits operation of the record function of either tape transport at locations away from the equipment cabinet. This unit contains the following controls and indicators: one three-position, center off, transport selector switch; one two-position, record-standby switch; two record lamps; two standby lamps; a meter; and a two-position channel selector switch.

The standby lamps illuminate continuously when the tape is threaded and transports are in the stop position. The lamps also act as end-of tape indicators by flashing when a transport is within five minutes of end of tape. The five minute warning is based on a tape speed of 7.5 ips. The time to end of tape will vary proportionately for the other tape speeds of 3.75 and 15 ips. When lit, the standby lamps do not indicate that proper tape speed is selected or that record levels have been adjusted.

The meter is used to monitor the record level of channel A or B, depending on the position of the channel selector switch.

TAPE TRANSPORTS

Two identical tape transports, one of which is shown in figure 11-10, are mounted on slides, one above the other in the electrical equipment cabinet, and are used to transport magnetic recording tape past the head assemblies which are mounted on the front of each transport between the supply and take-up reels. Operating speeds are 3.75, 7.5, and 15 ips for record and reproduce. For fast forward and rewind the speed is 300 ips averaged over 1200 feet of tape. Each tape transport has a control assembly made up of electronic parts, relays, etc., that control the operation of the individual tape transports. A bias defeat switch, located on the chassis of the control assembly, permits removal of the bias from channel B. A three-digit counter with reset knob is located on the front of each tape transport and provides an indication of tape usage.

Tape Drive Components

The tape drive components include a synchronous drive motor, a capstan and capstan idler, a reel idler, and a tape guide. The drive motor is a hysteresis synchronous motor with three windings to provide the three tape speeds. The motor shaft is attached to a flywheel pulley which drives the capstan by means of a nylon belt. The drive motor will start and the capstan will rotate as soon as power is applied. The drive belt tension is maintained by a spring-loaded pivot arm on which is mounted the CAPSTAND IDLER. The capstan idler consists of a rubber-tired idler wheel mounted on an arm which is attached to the shaft of a rotary solenoid. When the capstan idler solenoid is energized, it moves the idler arm against the capstan, providing a bearing surface for the capstan, which drives the magnetic tape at a constant speed.

A TAPE GUIDE positions the tape vertically with respect to the head assembly. A REEL IDLER smooths out any transient variations in tape speed originating in the tape supply reel.

Rewind and Takeup Components

The rewind and takeup components are identical in construction. Each consists of an induction motor, brake drum, and turntable.

The rewind motor and takeup motor are so connected that when power is applied, one motor operates at full torque and the other at reduced torque. In the record or reproduce mode, a series resistor is placed in each rewind and takeup motor circuit to reduce the normal torque of the motors while optimum tape tension is obtained at each reel.

The reels of tape are isolated from each other by the capstan and capstan idler. The capstan pulls the tape from the supply reel, overcoming the difference in torque of the rewind motor, which provides hold-back tension. A tape loop will be thrown when any malfunction of the equipment allows the feed rate to exceed the takeup rate. If the loop is sufficiently large, or if tape breakage occurs, the safety switch arm will be released to actuate the safety switch, and stop the equipment.

In the FAST FORWARD MODE of operation, the series resistor is removed from the takeup motor circuit, and a resistor is placed in the rewind motor circuit. The takeup and rewind motors operate at full and reduced torques, respectively, and the capstan pulls the tape from the supply reel (on the rewind turntable) to the takeup reel (on the takeup turntable), overcoming the reduced torque of the rewind motor. The tape tension is proportional to the difference in the forces exerted at the periphery of the two reels.

In the REWIND MODE of operation, the foregoing procedure is reversed. The resistor is removed from the rewind motor circuit, and a resistor is placed in the takeup motor circuit. The rewind motor will operate at full torque, the takeup motor at reduced torque, and the tape will be pulled from the takeup reel to the supply reel being held under tension by the reduced torque of the takeup motor.

When the equipment is being operated in any mode of tape travel, the correct tape tension is determined by the power applied to the rewind and takeup motors. However, when power is removed from these motors the forces exerted on the tape are removed, and the tape tension must be maintained by the operation of the brakes.

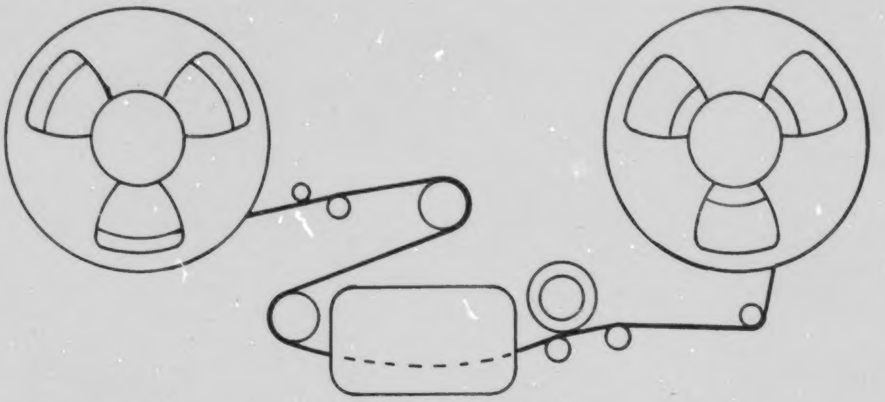
The brakes consist of brake drums attached to the shafts of the takeup and rewind motors and brake bands equipped with high-tension and low-tension springs, which determine the braking force applied for each direction of rotation. The brake bands are held from contact with the brake drums by the brake solenoid when the equipment is operated under any mode. When power is removed from the equipment the solenoid is deenergized and allows the brake bands to move into contact with the brake drums. To avoid throwing tape loops as the tape comes to a stop, it is necessary that the braking force on the trailing turntable (turntable from which tape is being pulled) always be greater than that which is applied to the leading turntable (turntable which is taking up the tape). However, the braking differential must not be so great that the tape is in danger of being deformed or broken.

Head Assembly

The head assembly consists of erase, record, and reproduce heads. In the record or reproduce modes of operation, a point on the tape will pass over the erase, record, and reproduce heads in that order. The outer tracks of the record and reproduce heads are for channel A, and the inner tracks are for channel B. The erase head is full track, and thus erases the full width of the tape on both channels.

OPERATION

As an IC Electrician you will normally operate the AN/UNQ-7E set only when necessary to



7.54(140B)

Figure 11-11.—Tape threading path.

troubleshoot it. All functions of the set can be operated at the front of the equipment cabinet. Only the record and stop functions can be operated at the RCU. Operating the set is similar to operating a basic tape recorder. You should be able to do so by carrying out the instructions that follow.

Pre-operation Procedure

Before operating the equipment, take the following steps. Rotate all dimmer mechanisms on indicator lights counterclockwise to their full open positions. Turn the power switch (on central control panel) to ON. Observe that the white power lamp is lit. Place a full reel of tape on the supply turntable of the selected tape transport, No. 1 or No. 2, and an empty reel on the take-up turntable. Next, thread the tape from the supply reel through the tape head and onto the take-up reel as shown in figure 11-11. Then set the tape counter to the 000 position, and the speed selector on the tape transport to the desired speed. Finally, adjust the input level. The channel A and channel B record levels, as monitored by the meters, are set by the record level controls on the recorder—reproducer control panel. It is not necessary to be in the record mode of operation to obtain record level indications.

Recording

After taking the last pre-operation step, you record by turning both record switches to position 1 or 2, depending on the tape transport selected. Make sure that the tape begins to move forward at the correct speed, and that the red record lamp for this tape transport comes on. To stop the tape transport, simply press its stopbutton. Observe that the tape stops moving and the red record lamp goes out.

Reproducing

After taking the last pre-operation step, you can reproduce by turning the reproduce switch to position 1 or 2, depending on the tape transport selected. Make sure that the tape moves forward at the correct speed and that the green reproduce lamp comes on. As in recording, you stop the tape transport by pressing its stopbutton. Notice that the tape stops and the green reproduce light goes out.

Recording from Remote Control Unit

In operating a tape transport from the RCU, be sure that both standby amber lamps are lit (an indication that power is applied and that the tape is threaded properly). To record from the RCU, move the TRANSPORT selector switch to position 1 or 2, depending on the transport selected. Then position the RECORD-STANDBY switch to record. Check to see that the standby lamp for the selected tape transport goes out and that the red record lamp comes on. To stop recording from the RCU, return the RECORD-STANDBY switch to the standby position, and the

TRANSPORT switch to its OFF position. Observe that the standby lamp comes on and the record lamp goes out.

Rewinding

If the tape is threaded on the recorder-reproducer and is not in motion, you can move it rapidly in either the forward (fast forward) or reverse (rewind) direction by placing the rewind-fast forward switch S1 in the appropriate position. You can stop the moving tape by returning this switch to its OFF position. The tape-motion components will be automatically deactivated at the end of a reel.

COMMERCIAL TAPE RECORDER/REPRODUCERS

This section is concerned only with the operating principles of a typical single-motor tape transport as used in commercial tape recorder-reproducers (tape decks).

MODES OF OPERATION

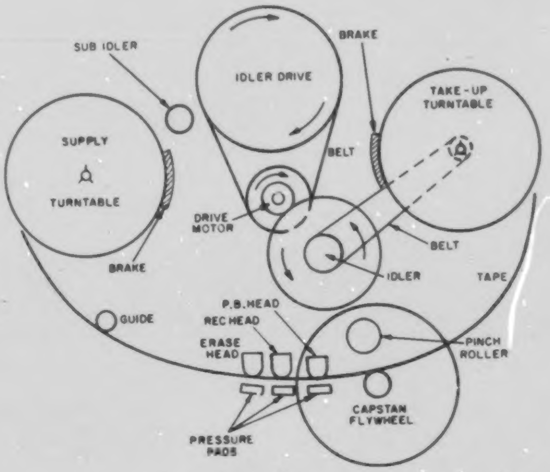
The operating modes for a tape deck are STOP, RECORD/PLAYBACK, and REWIND/FAST FORWARD. A pushbutton or switch is operated to select the desired mode. Depending on the mode selected, the tape transport mechanism enables the tape to move, or keeps it from moving, from the supply turntable (reel) to the takeup turntable.

Stop Mode

The mechanism shown in figure 11-12 is in the STOP mode. Notice that the brakes are engaged and the drive idler is disengaged from the capstan flywheel. The motor is running, and the idler drive and idler wheels rotate in the directions indicated by the arrows.

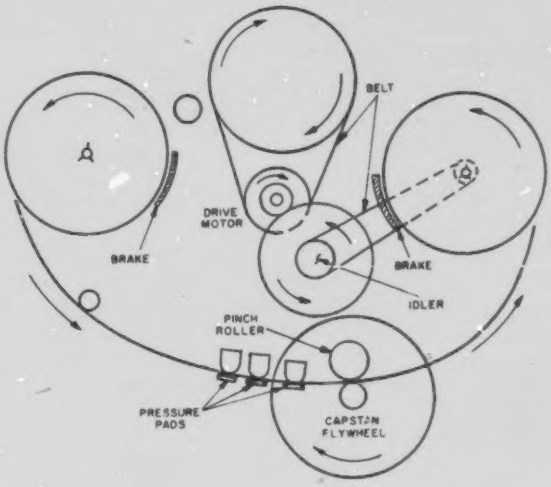
Record/Playback Mode

When the mode selector switch is moved to the record or playback setting, the brakes release and a cam engages the drive train between the drive motor and the capstan flywheel. The pressure pads move the tape into contact with the heads, and the rubber pinch roller moves to hold the tape firmly between it and the rotating capstan. The tape is now driven as shown in figure 11-13. The belt connecting the drive motor idler to the takeup turntable drives the turntable at a rate slightly faster than necessary to take up the tape. The turntable will, however, turn at a constant rate even as the circle of tape on the takeup reel increases in diameter because the drive belt is designed to slip on the takeup reel spindle. The takeup reel and the pinch


SUB IDLER
IDLER DRIVE
BRAKE
TAKE-UP TURNTABLE
SUPPLY
TURNTABLE
BELT
DRIVE MOTOR
BELT
BRAKE
IDLER
TAPE
P.B. HEAD
REC HEAD
GUIDE
ERASE HEAD
PINCH ROLLER
CAPSTAN FLYWHEEL
PRESSURE PADS

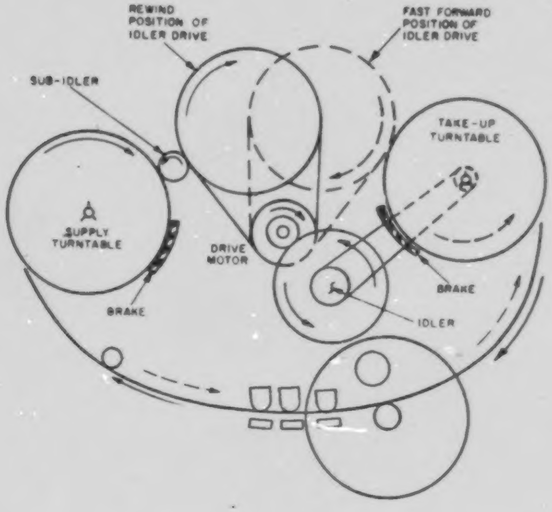
140.136

Figure 11-12.—Tape transport mechanism in stop position.


BELT
DRIVE MOTOR
BRAKE
BRAKE
IDLER
PINCH ROLLER
PRESSURE PADS
CAPSTAN FLYWHEEL

140.137

Figure 11-13.—Tape transport mechanism in record or playback position.



140.138
Figure 11-14. — Tape transport mechanism in rewind or fast forward position.

roller capstan drive combine to move the tape past the heads at a constant speed.

Rewind/Fast Forward Mode

With the mode selector switch in REWIND or FAST FORWARD, the tape transport mechanism is positioned as shown by figure 11-14. The brakes disengage, the pressure pads move away from the heads, and the pinch roller moves away from the capstan. Also, the drive train disengages from the capstan flywheel. Now the tape can pass freely from reel to reel. In the FAST FORWARD mode, the high speed idler drive wheel is shifted into contact with the takeup turntable so that the tape will move quickly onto the takeup reel. In the REWIND mode, the idler drive wheel is shifted in the opposite direction and pushes the sub idler so as to drive the supply wheel at high speeds, thereby rewinding the tape onto the supply turntable.

TAPE RECORDER MAINTENANCE

Tape recorder maintenance includes cleaning, adjusting, demagnetizing tape heads, tape erasing, and tape splicing. Just as in other well-designed electromechanical devices, most troubles in tape recorder/reproducers are usually cleared up by routine cleaning or minor mechanical adjustment.

CLEANING

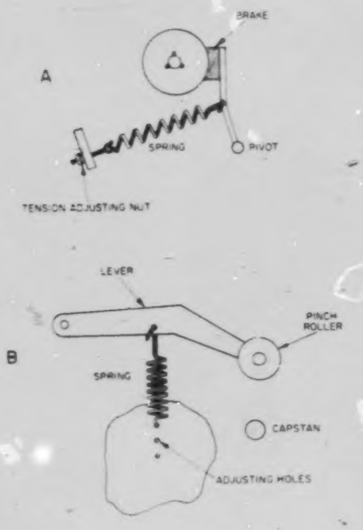
The largest single reason for tape deck operators complaining about poor quality of reproduction is dirty tape heads. As the tape deck is used, an oxide from the tape surface rubs off and builds up on the face of the heads. The deposit prevents the tape from making good contact with the tape head, causing a reduced output and sometimes magnetically short circuiting the gap between the heads. Clean the heads with the tip of a cotton swab dipped in alcohol or in a commercial tape head cleaner.

Binding or worn drive wheels and pulley belts of the tape transport result in almost as many trouble calls as the heads. A dirty or worn belt can cause the output to flutter or the tape speed to vary. Remove all traces of oil or dirt from belts and rubber-tired drive wheels with alcohol. You should take the pulleys and drive wheels off their shafts and clean them at regular intervals. After reassembly, apply a light coat of machine oil to all bearing surfaces. When a machine is being repaired in the shop, have it cleaned and vacuumed. If cleaning the belts or wheels does not correct the fault, then replace the parts with new ones.

MECHANICAL ADJUSTMENTS

The alignment of the tape heads is important for proper operation of the recorder/reproducer. Usually the tape heads must be aligned in azimuth and height only while playing a test tape. Test tapes are available through electronic supply stores, and contain complete directions for their use.

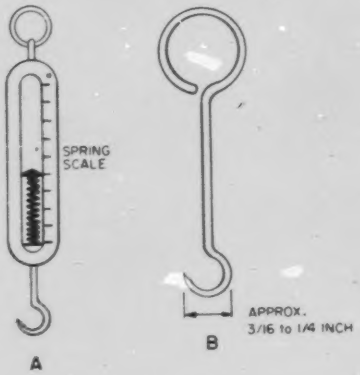
Most tape recorders use springs to maintain tension on the pinch roller and the brake shoe. Usually you can adjust the tension by turning a nut (fig. 11-15A) or attaching the spring to a different hole (fig. 11-15B). If there is no way to adjust the spring tension, replace the spring with a new one. Adjusting the tension on the pinch roller spring requires the use of a spring scale, such as the one shown in figure 11-16A. Spring scales are available from commercial electronics supply stores. In using a spring scale, follow the instructions furnished by the manufacturer of the tape deck. A handy tool for hooking the springs from hole to hole can be made from a firm piece of wire. See figure 11-16B. This tool reduces the chance of the spring flying off when you are unhooking it.



140.139
Figure 11-15A.—Spring tension adjusted by a lock nut. B.—Spring tension using holes to adjust tension.

DEMAGNETIZING TAPE HEADS

In normal use, the tape heads become magnetized and lose their fidelity or ability to reproduce sound accurately. A demagnetizer safely removes the magnetism from the heads to restore the loss in fidelity. Though the shapes of demagnetizers may differ slightly according to the model, they are normally hand held and about the size of a pen light. It is best to demagnetize the heads after they are cleaned. First remove all head covers and shields, then plug the demagnetizer into a 115-volt a-c power source. Bring the tips of the demagnetizer close to the head, straddling the head gap with the tips of the demagnetizer. Never allow the tips of the demagnetizer to touch the surface of the tape head. Slowly move the demagnetizer up and down, three or four times, along the entire length of the head and at the same time pull the demagnetizer away from the head in a slow, steady motion, allowing the influence of the alternating current to gradually die away. Repeat this process with the capstan and the tape guides. Then remove the demagnetizer and disconnect its power source.



140.140
Figure 11-16.—Spring scale and spring removal tool.

ERASING MAGNETIC TAPE

Magnetic tape recording is economical because the tape can be erased and reused over and over again with little or no loss in the quality of recording. Erasing is done by means of a bulk eraser or the erase head of the tape recorder/reproducer.

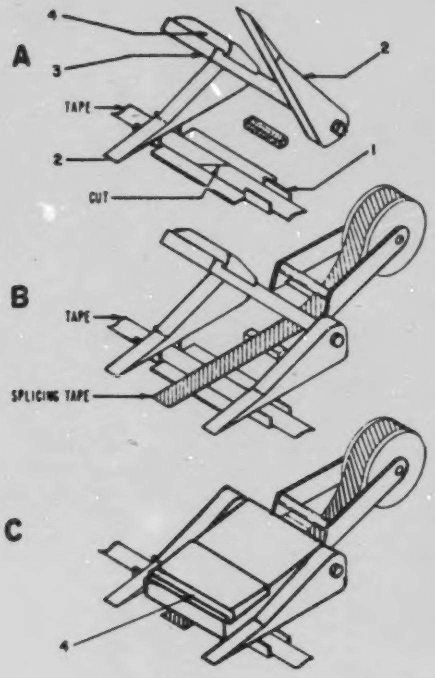
Bulk erasing will completely and quickly erase an entire reel of tape, usually in less than a minute. In erasing, you place the reel of tape on a bulk eraser, then subject the tape to a strong alternating magnetic field. Start with a maximum amount and slowly taper off to zero. This magnetic field leaves the tape in a demagnetized or "degaussed" state. The tape reverts to a neutral condition with all previously recorded information removed. Since each bulk eraser differs slightly in operation, be sure to follow the manufacturer's instructions.

When using the erase head of the recorder/reproducer, thread the tape in the normal manner, then turn the record level to the lowest position. Make sure that all microphones are unplugged. Select the fastest tape speed and turn the mode selector switch to the record position.

SPLICING MAGNETIC TAPE

You can repair breaks in magnetic tape by cutting the broken ends and splicing the cut ends together.

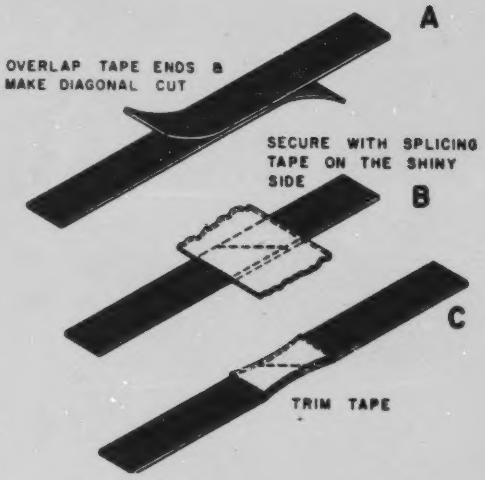
Also, you can cut out a piece of tape or add another piece to the existing tape. To make a strong and otherwise superior splice or joint, be sure to use only the kind of tape that is designed for splicing magnetic tape and a machine, such as the one shown in figure 11-12.



140.91(140B)A
Figure 11-17.—Magnetic tape splicing.

Splicing is a relatively simple technique. For best results, follow the procedure below step by step.

- Insert the overlap cut or broken ends of magnetic tape in tape guides (1). Lower the tape holding fingers (2).
- With operating lever (3) up, slide position control knob (4) to CUT position. Press operating lever down with just enough pressure to cut tape. Lift lever and blow excess tape away (fig. 11-17A).


A
OVERLAP TAPE ENDS & MAKE DIAGONAL CUT
SECURE WITH SPLICING TAPE ON THE SHINY SIDE
B
C
TRIM TAPE

140.91(140B)B
Figure 11-18.—Magnetic tape splicing.

- Pull splicing tape forward and apply to cut tape (fig. 11-17B).
- Position control knob forward to TRIM position and press down (fig. 11-17C). Lift operating lever and fingers. Remove spliced tape.
- Remove any excess tape that adheres to cutter.

You may also splice tape by hand, using a sharp pair of scissors or a knife. First hold the cut or broken ends of the magnetic tape so they overlap as shown in figure 11-18A. With the magnetic tape properly aligned, cut diagonally through both pieces of tape. Clear away the loose ends and place the tape on a clean and dry surface, making sure the shiny side is up. Next, place a piece of splicing tape across the cut (fig. 11-18B). After the splicing tape adheres to the magnetic tape, trim the excess splicing tape as shown in figure 11-18C.

CHAPTER 12

GYROCOMPASSES, PART I

The ship's gyrocompass system is an important responsibility of the Interior Communications Group. In case this system fails, the ship could not perform some missions at all (gunfire support, for example). Other missions, such as ASW and underway replenishment, could be carried out only with difficulty and increased risk.

This chapter describes the principles and applications of basic north-seeking and north-indicating gyroscopes, including how they are designed for use as shipboard gyrocompasses.

THE FREE GYROSCOPE

The gyroscope is a heavy wheel, or rotor, suspended so that its axle is free to turn in any direction. As you can see in figure 12-1, the rotor axle is supported by two bearings in a ring. This ring is supported by means of studs and bearings in a slightly larger outer ring. The two rings are called gimbals. The outer gimbal is mounted in a supporting frame by two bearings.

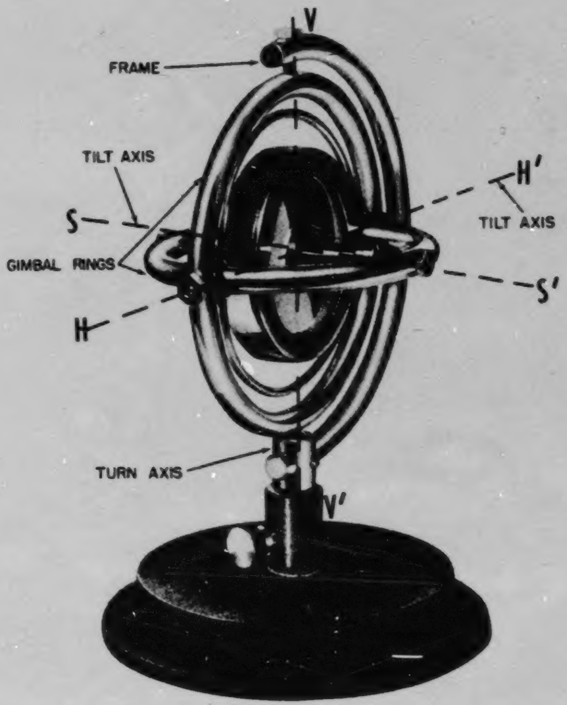
The rotor and the two gimbals are pivoted and balanced about their axes. The axes are perpendicular to each other, and intersect at the center of gravity of the rotor. The bearings of the rotor and gimbals are virtually frictionless, and have almost no effect on the operation of the gyro.

THREE DEGREES OF FREEDOM

The gimbal mounting permits the rotor to turn in three planes, giving it three so-called degrees of freedom: (1) freedom to spin, (2) freedom to turn, and (3) freedom to tilt. The three degrees of freedom permit the rotor to assume any position within the supporting frame (fig. 12-1). The rotor is free to spin about its own axle, spinning axis S-S', giving the first degree of freedom. The inner gimbal ring is free to rotate on its bearings about the horizontal axis, H-H', giving the second degree of freedom. The outer gimbal ring is free to rotate on its bearings about the vertical axis, V-V', giving the third degree of freedom.

GYROSCOPIC PROPERTIES

When the gyroscope rotor is spinning it develops two characteristics, or properties, that



77.194

Figure 12-1.—The gyroscope.

it does not have when at rest. These properties make it possible to convert the gyroscope into a gyrocompass. They are rigidity of plane and precession.

Rigidity of Plane

When the rotor of a gyroscope is set spinning with its axle pointed in one direction (fig. 12-2A) the rotor continues to spin with its axle pointing in the same direction, no matter how the frame of the gyroscope is tilted or turned (fig. 12-2B). As long as the bearings are frictionless and the rotor spins, no turning of the supporting frame can change the plane of the rotor with respect to space. This property of the gyroscope is called rigidity of plane. Other names for the same property are gyroscopic inertia and stability.

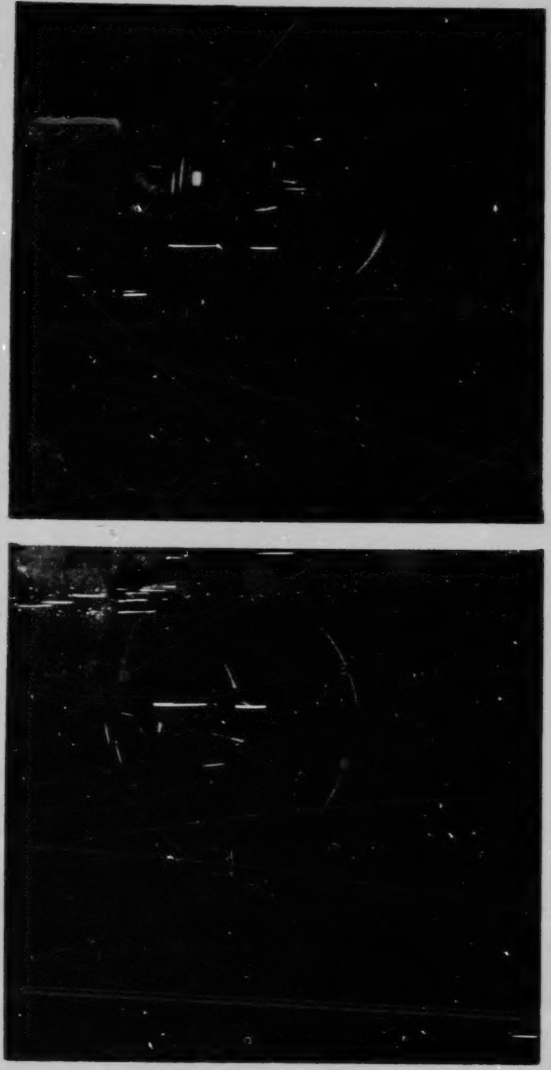


Figure 12-2.—Rigidity of plane of spinning gyroscope. 27.128(27B)

Newton's first law of motion states that a body in motion continues to move in a straight line at a constant speed unless acted on by an outside force. Any point in a spinning wheel tries to move in a straight line, but being a part of the wheel, must travel in an orbit around the axle. Although each part of the wheel is forced to travel in a circle, it still resists any other change. Any attempt to change the alignment or angle of the wheel is resisted by both the mass of the wheel and the velocity of that mass. The combination of mass and velocity is the kinetic energy of the wheel, and this kinetic energy is applied to give the rotor rigidity of plane.

A gyroscope can be made more rigid by making the rotor heavier, causing the rotor to spin faster, and concentrating most of the rotor weight near the circumference. If two rotors with cross sections like those shown in figure 12-3 are of equal weight and rotate at the same speed, the rotor in figure 12-3B is more rigid than the rotor in figure 12-3A. This condition exists because the weight of the rotor in figure 12-3B is concentrated near the circumference. Both gyroscope and gyrocompass rotors are shaped like the rotors shown in figure 12-3B.

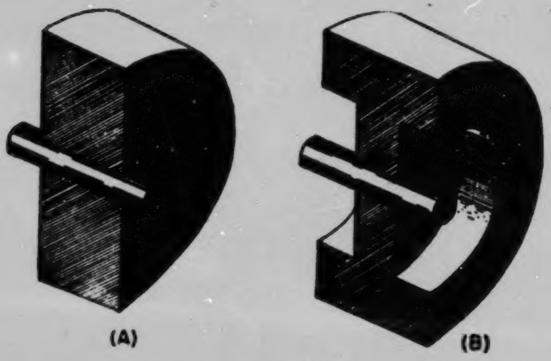


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Figure 12-3.—Weight distribution in rotors.

Precession

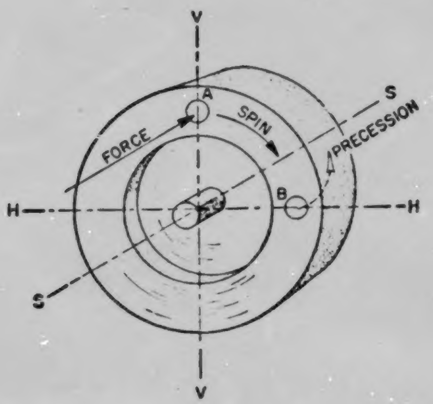
Precession describes how a gyro reacts to any force that attempts to tilt or turn it. Though vector diagrams can help explain why precession occurs, it is more important to know how precession affects gyro performance.

The rotor of a gyro has one plane of rotation as long as its axle is aligned with, or pointed at, one point in space. When the axle tilts, turns, or wobbles, then the plane of rotation of the rotor changes. Plane of rotation means the direction that the axle is aligned or pointed.

Torque is a force that tends to produce rotation. Force acts in a straight line, at or on a point. Torque occurs within a plane and about an axle or axis of rotation. For a given amount of force, the torque is greater as it is applied to a point farther from the axis. If the force acts directly on a point on the axis, no torque is produced.

Because of precession a gyro will react to the application of torque by moving at right angles to the direction of the torque. If the torque is applied downward against the end of the axle of a gyro which is horizontal, the gyro will swing to the right or left in response. The direction in which it will swing depends on the direction the rotor is turning.

A simple way to predict the direction of precession is illustrated in figure 12-4. The force that tends to change the plane of rotation of the rotor is applied to point A at the top of the wheel. This point does not move in the direction of the applied force, but a point displaced 90° in the direction of rotation moves in the direction of the applied force. This is the direction of precession.



27.131
Figure 12-4.—Direction of precession.

Any force that tends to change the plane of rotation causes a gyroscope to precess. Precession continues as long as there is a component of force acting to change the plane of rotation and precession ceases immediately when the force is removed. If the plane through which the force is acting remains unchanged, the gyroscope precesses until the plane of the rotor is in the plane of the force. When the position is reached, the force is about the spinning axis and can cause no further precession.

If the plane in which the force acts moves at the same rate and the same direction as the precession which it causes, the precession will be continuous. This is illustrated by figure 12-5 in which the force attempting to change the plane of rotation is provided by a weight W suspended from the end of the horizontal axle. Although the weight is exerting a downward force, it must be remembered that the force it produces against the particles in the spinning wheel is horizontal. This force is imparted to the particles in the wheel as exemplified by arrows F and F'. If the wheel rotates clockwise as seen from the weighted end, precession will occur in the direction of arrow P. As the gyroscope precesses it carries the weight around with it so that forces F and F' continuously act at right angles to the plane of rotation and precession continues indefinitely.

FORCE OF TRANSLATION

Any force operating through the center of gravity of the gyroscope does not change the angle of the plane of rotation but moves the gyroscope as a unit without changing its position in space. Such a force operating through the center of gravity is known as a force of translation. Thus, the spinning gyroscope may be moved freely in space by means of its supporting frame, without disturbing the plane of rotation of the rotor. This condition exists because the force that is applied through the supporting frame acts through the center of gravity of the rotor and is a force of translation. It produces no torque on the gyro rotor.

EFFECT OF EARTH'S ROTATION

As just explained, a free-spinning gyroscope can be moved in any direction without altering

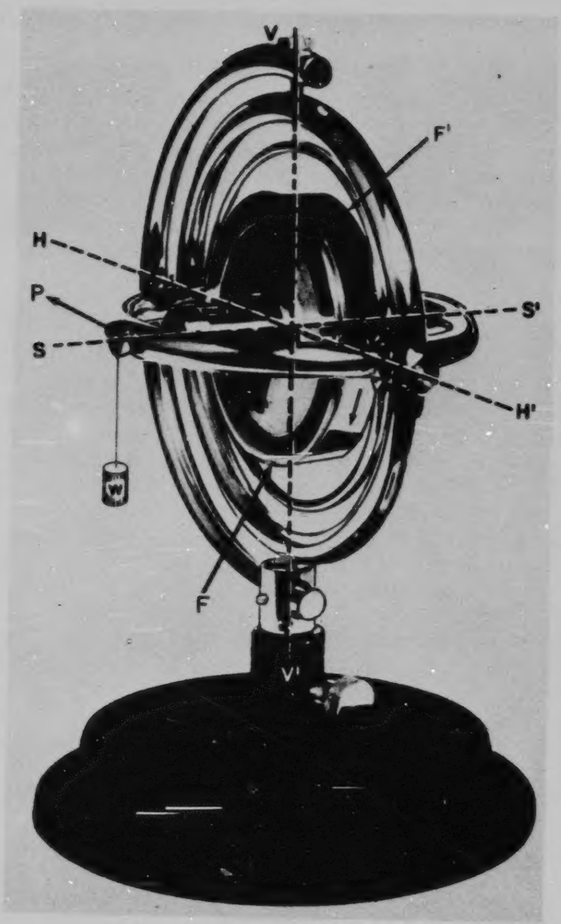


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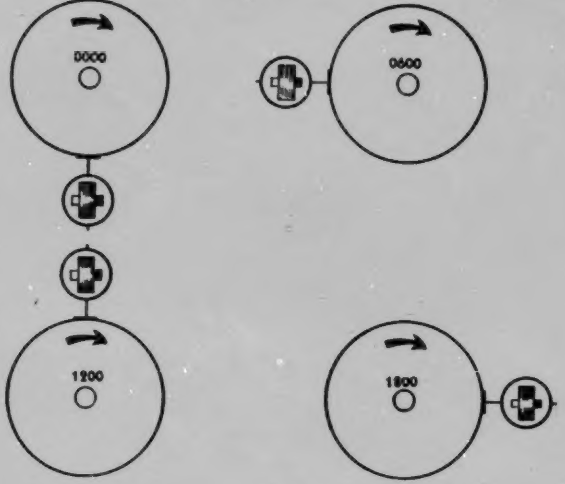
Figure 12-5.—Continuous precession.



12.144(77A)A
Figure 12-6.—Free gyroscope at the Equator viewed from space.

the angle of its plane of rotation. If this free-spinning gyroscope is placed on the earth's surface at the equator, with its spinning axis horizontal and aligned east and west, an observer in space below the south pole would note that the earth rotates clockwise from west to east and carries the gyroscope along. As the earth rotates, rigidity of plane keeps the gyroscope wheel fixed in space and rotating in the same plane at all times. Figure 12-6 shows how this gyroscope would appear. Assume that the gyroscope is set spinning at 0000 hours with its spinning axis aligned east and west and parallel to the earth's surface. At 0600, 6 hours after the gyroscope was started, the earth has rotated 90° and the axle of the gyroscope is aligned with the original starting position. At 1200 the earth has rotated 180° while the gyroscope retains its original position. The figure shows how the gyro completes a full cycle in a 24-hour period.

APPARENT ROTATION OF THE GYROSCOPE

An observer on the earth's surface does not see the operation of the gyro in the same way as an observer in space does. On the earth the gyro appears to rotate, while the earth stands still. As the earth rotates the observer moves with it, so the gyroscope seems to rotate around its horizontal axis. The effect the observer sees on the earth is called apparent rotation, and also is referred to as horizontal earth rate effect. If the gyro were started with its axle vertical at one of the earth's poles it would remain in that position, and produce no apparent rotation around its horizontal axis. Figure 12-7 illustrates the effect of apparent rotation at the equator, as seen over a 24-hour period.

Now assume that the spinning gyroscope, with its spinning axis horizontal, is moved to the

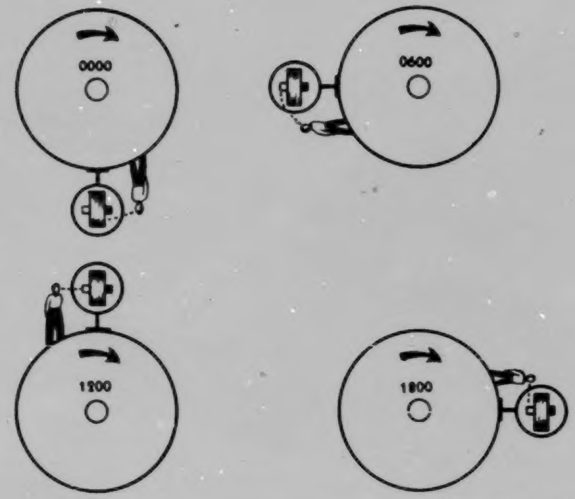


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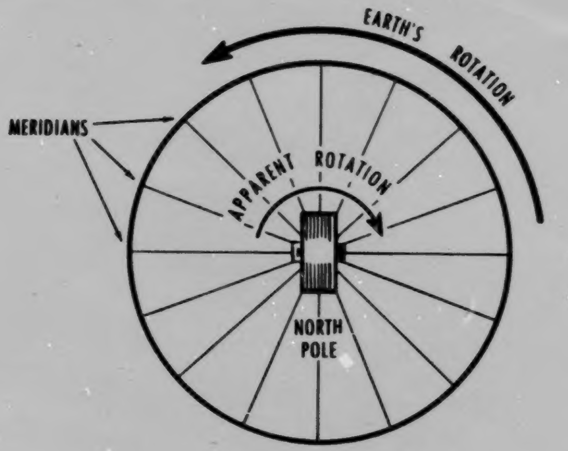
Figure 12-7.—Free gyroscope at the Equator viewed from the earth's surface.

North Pole (fig. 12-8). To an observer on the earth's surface the gyroscope appears to rotate about its vertical axis. To an observer in space the gyroscope axle appears to remain fixed and the earth appears to rotate under it. This apparent rotation about the vertical axis is referred to as vertical earth rate effect. It is maximum at the poles and zero at the Equator.

When the gyroscope axle is placed parallel to the earth's axis at any location on the earth's surface, the apparent rotation is about the axle of the gyroscope and cannot be observed. At any point between the Equator and either pole, a gyroscope whose spinning axis is not parallel to the earth's spinning axis has an apparent rotation that is a combination of horizontal earth rate and vertical earth rate.

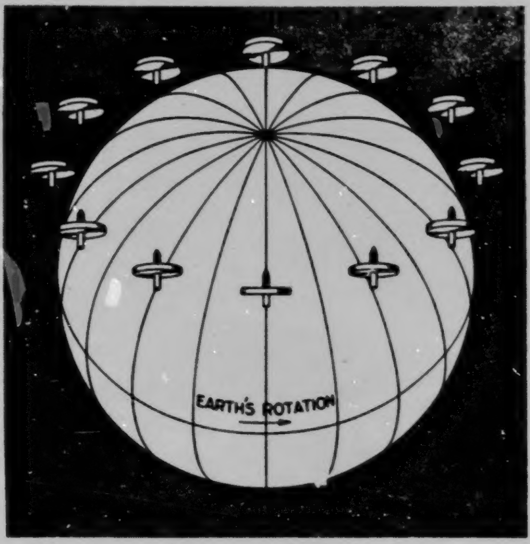
The combined earth rate effects at this point make the gyro appear to rotate partly about the horizontal axis and partly about the vertical axis. The horizontal earth rate causes the gyro to tilt, whereas the vertical earth rate causes it to move in azimuth with respect to the earth. The magnitude of rotation depends on the latitude of the gyro.



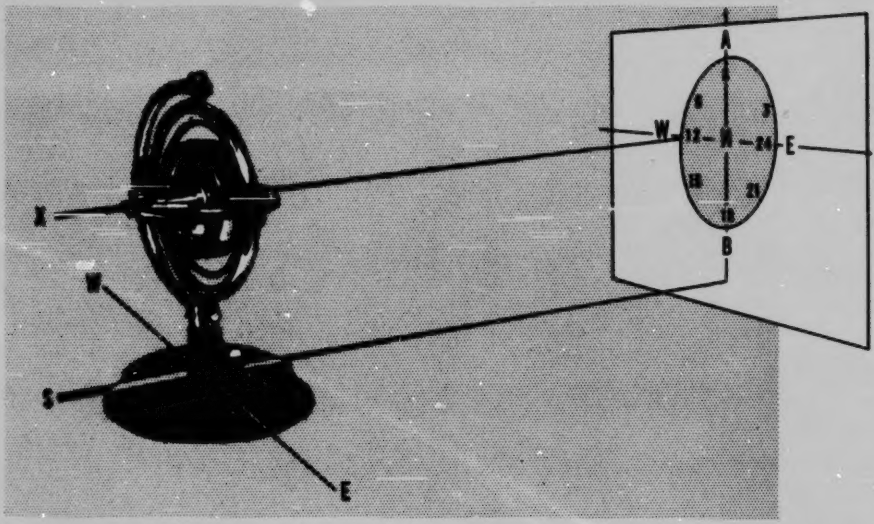
77.198
Figure 12-8.—Apparent rotation of a gyroscope at the North Pole.

Apparent rotation is illustrated by placing a spinning gyroscope with its axle on the meridian (aligned north-south) and parallel to the earth's surface at 45° north latitude and 0° longitude, as shown in figure 12-9.

A gyroscope, if set on any part of the earth's surface with the spinning axle not parallel to the earth's polar axis, appears to rotate, over



77.199(140B)
Figure 12-9.—Apparent rotation of a gyroscope at 45° N latitude.



77.200

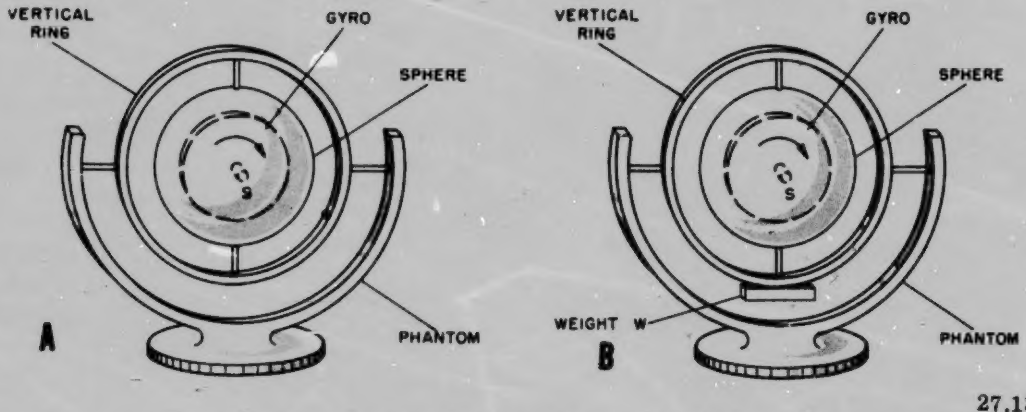
Figure 12-10.—Path of the spinning axle of a free gyroscope.

a 24-hour period, about a line passing through the center of the gyroscope and parallel to the earth's axis. This apparent rotation is in a counterclockwise direction when viewed from south to north. The path that the north axle describes in space is indicated by the line EAWB back to E (fig. 12-10).

The effect of the earth's rotation causes the north end of the gyroscope axle to rise when east of the meridian and to fall when west of the meridian in any latitude. This tilting effect provides the means by which the gyroscope can be made into a north-seeking instrument.

MAKING THE GYROSCOPE A GYROCOMPASS

Before a simple gyroscope can be made into a gyrocompass, its mounting must be changed as shown in figure 12-11A. Here, the basic gyro is modified by replacing the inner gimbal with a sphere or case, a feature of all compass gyro which serves to protect the rotor. A vacuum



27.135:.136

Figure 12-11.—A. Simple gyroscope, B. Modified gyroscope.

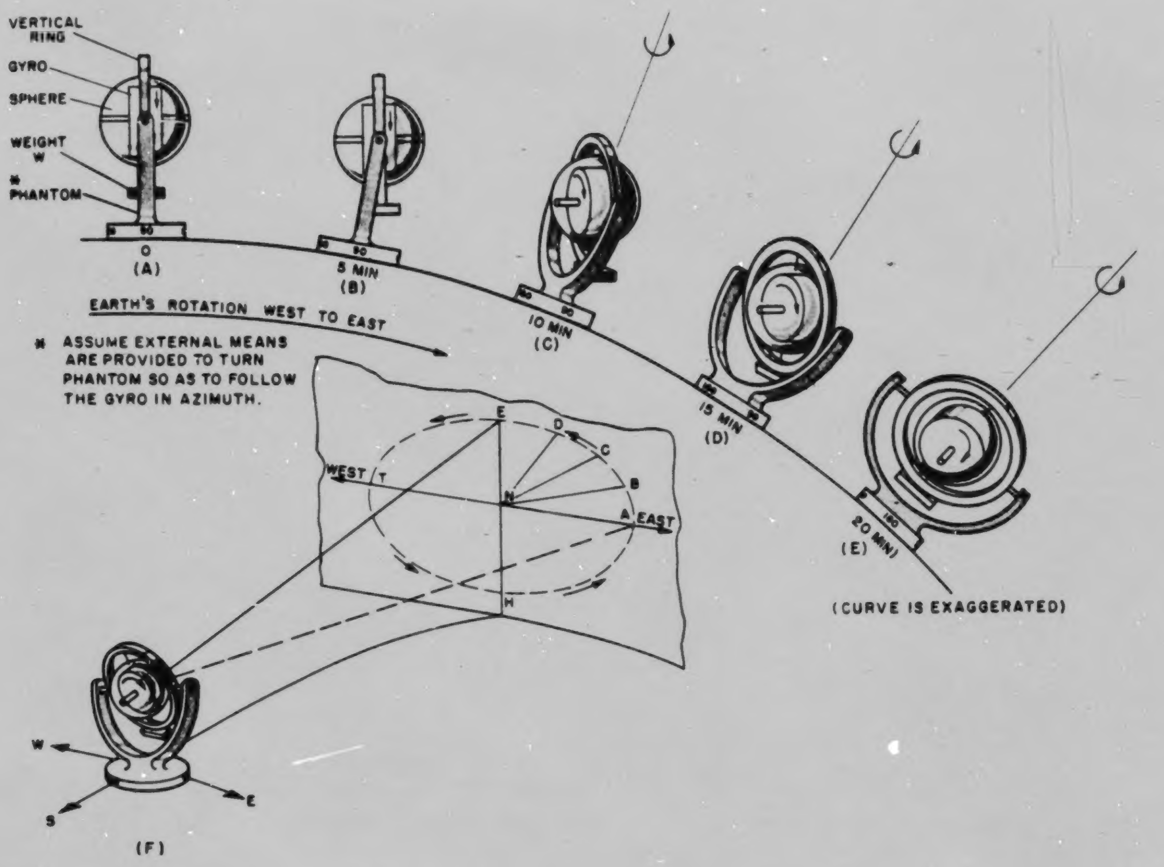

VERTICAL RING
GYRO
SPHERE
WEIGHT W
* PHANTOM
90
0
(A)
90
5 MIN
(B)
90
10 MIN
(C)
90
15 MIN
(D)
180
20 MIN
(E)
EARTH'S ROTATION WEST TO EAST
* ASSUME EXTERNAL MEANS ARE PROVIDED TO TURN PHANTOM SO AS TO FOLLOW THE GYRO IN AZIMUTH.
E
D
C
B
WEST
T
N
A
EAST
H
W
S
E
(F)
(CURVE IS EXAGGERATED)

Figure 12-12.—Effect of weight and earth's rotation on the gyroscope. 27.137

in the sphere cuts down air friction on the spinning rotor. In another modification, the base is replaced with a phantom ring, or phantom. The phantom differs from the base of a simple gyro in that it is turned by a servomechanism to follow the horizontal angle of the gyro axle. The phantom provides the vertical ring with freedom to tilt and freedom to turn. With this modified mounting the gyro maintains its plane of rotation as long as it spins and nothing touches it.

There must also be a means for making the gyro seek out and point to true north. For the purposes of this explanation, true north is the direction along the meridian plane from the point of observation to the north pole, and is the horizontal direction relative to the point of observation. In other words, it is the direction a magnetic compass would point if the North Pole and magnetic north pole were at the same place.

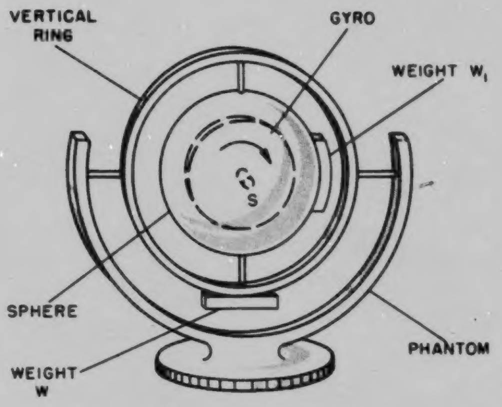
To become a gyrocompass the gyro must be modified so it can:

1. align its axis on the meridian plane
2. align its axis nearly horizontal
3. maintain its alignment horizontally and on the meridian once attained.

In figure 12-11B, a weight has been added to the vertical ring, making it bottom heavy, or pendulous. Because of the additional freedom given by the phantom this weight will exert a force on the gyro whenever the rotor is not level with the earth.

To understand how this pendulous weight affects the gyro, remember that the rotor is spinning in the same direction as the earth when the gyro points north and that the weight will not move the rotor to a level position, but will precess it horizontally. Figure 12-12 shows how the modified gyro acts. It does not steady on north, but oscillates equally from one side to the other of the desired direction. The period of oscillation is much less than the 24 hours required for an unmodified gyro; the actual time is determined by the weight and speed of the rotor, and the amount of the pendulous weight. The greater this weight, the faster the precession, therefore there is less time for horizontal earth rate to cause tilt. The gyro now seeks north, and the next step is to modify it so it will come to rest on the north-south meridian, indicating the direction of true north.

To make a gyro a north seeking compass it is necessary to suppress the movement of the gyro about the meridian. Therefore, a smaller weight is added on the "east" side of the rotor case or gyro sphere. This weight, W1, is shown in figure 12-13. With the gyro axle level, the torque produced by gravity acting on weight W1 is restrained by the vertical axis bearings. When the gyro tilts because of earth rate, the weight and gravity causes a torque to act around the vertical axis. Because the rotor is spinning the torque produced by weight W1 causes precession which tends to level the gyro.

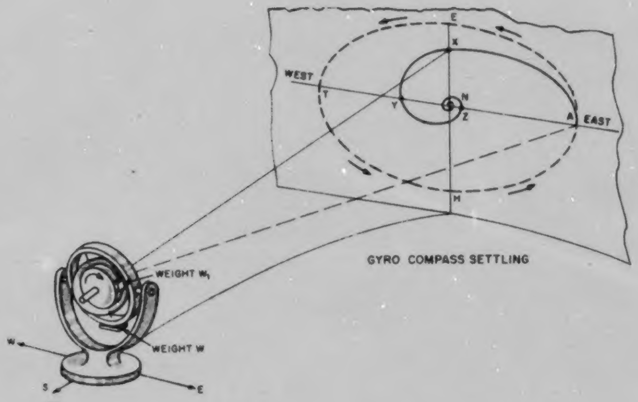


27.138

Figure 12-13.—Gyroscope with weights on the vertical ring and sphere.

Both weights, W and W1, influence the gyro when it is not aligned with the meridian. When the gyro is started while pointed away from the meridian it is caused to tilt by the effect of earth rate. As a result of the leveling action of W1, it tilts less when the action of weight W brings it to the meridian than it did with only weight W. Having less tilt applied as it traverses the meridian means that it cannot overshoot as much to the other side. If started to the east of the meridian this gyro does not precess as far to the west as it was to the east at the beginning of the oscillation.

The oscillation continues, however, and after reaching its westerly limit the north end of the gyro tilts downward. The gyro now precesses across the meridian to the east, but again the precession is less due to the reduced tilt



27.139

Figure 12-14.—Effect of weights on the gyroscope.

caused by W1. Since each successive oscillation is reduced, the path is spiral-shaped instead of elliptical. See figure 12-14.

Considering the action of the weights, you can see that in the only position of rest possible for the gyro, its axle is horizontal and on the meridian. The free gyroscope has become a gyrocompass, able to settle only on the meridian and level. The addition of W1 changed it from a north-seeking to a north-indicating gyro. The period, or amount of time to complete each oscillation, can be decreased by increasing weight W.

This basic north-indicating gyro operates satisfactorily only at the Equator and when mounted on a stable platform. More design improvements must be made so it can contend with the acceleration and motion of a ship, and with the effects of changes in latitude.

STABILIZING THE GYROCOMPASS

To allow the gyro to function as a compass on a ship, and over a wide range of latitudes, there must be a way to stabilize it when it is level with the earth's surface instead of the earth's axis. Also, the effects of ship's acceleration and deceleration must be damped, otherwise they would soon put the compass out of line if it were fitted with only the two weights of the basic gyrocompass. All of the several methods of stabilizing a gyrocompass involve some form of damping. Two simple methods, used in older gyrocompasses, are described in this chapter. Both methods use the effects of weight and hydraulic action to damp movements and stabilize the gyrocompass.

PENDULOUS METHOD

Gyrocompasses made by ARMA use pendulous weight W; however, weight W1 is replaced by an oil ballistic as shown in figure 12-15.

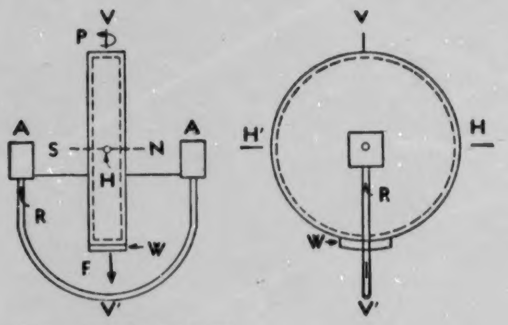
Two tanks, partly filled with a light oil, are secured to the rotor case in line with the north-south rotor axle on opposite sides of the rotor. The tube that connects the tanks has a small opening so that the oil flows slowly from one tank to the other.

The action of the damping is delayed because of the small opening in the tube. The effect of this damping lags behind that of the pendulous weight.

If the north end of the gyroscope axle is elevated, the pendulous weight exerts a downward force on the high, or north, axle. At the same time oil begins to (1) flow from the north tank to the south tank and (2) exert a small force on the low, or south, end. Because of the small opening in the tube, the flow of oil is not effective for some time. If the tilt is maintained long enough, however, sufficient oil accumulates in the south tank to reduce the effect of the pendulous weight on the high end of the axle. The longer the tilt is maintained, the greater is the amount of oil in the south tank and the smaller is the net force exerted by the pendulous weight on the north axle.

If the tilt is reversed and the south axle is elevated the excess oil in the south tank acts on the high end of the axle. The small opening in the tube prevents the oil from flowing immediately into the north tank. Hence, for a short time after the tilt is reversed the weight of the oil in the south tank adds to the force exerted by the weight on the high south axle.

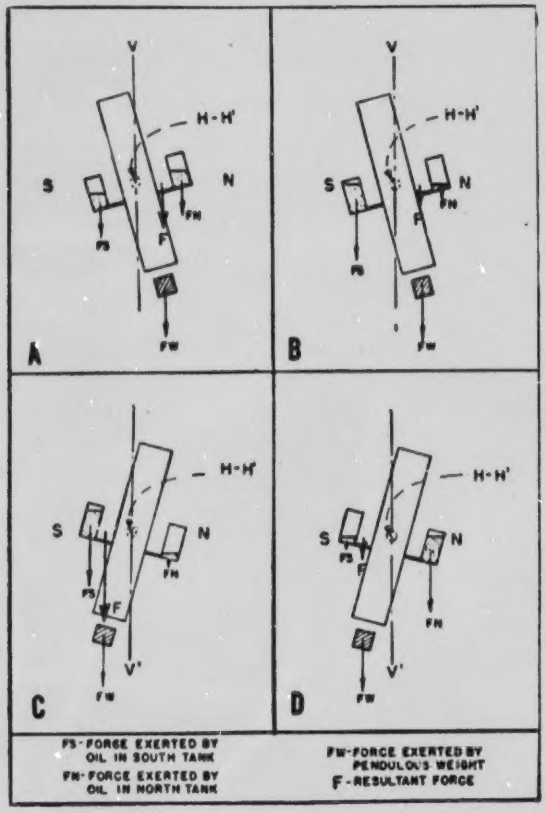
In figure 12-16A, the axle has just been tilted with the north end up, and the oil has not had sufficient time to run into the south tank in any great amount. In figure 12-16B, the tilt has been maintained long enough for a large amount of oil to flow into the south tank, and the resultant force is greatly reduced. In figure 12-16C, the tilt has just been reversed and there is still excess oil in the south tank. This excess oil adds to the pendulous weight and results in an increased force. In figure 12-16D, the south axle has been tilted up for some time and the



S, N —SPINNING AXIS
V, V' —VERTICAL AXIS
H, H' —HORIZONTAL AXIS
A, A —OIL TANKS WITH PIPE CONNECTION
R —RESTRICTED OPENING IN OIL LINE
W —WEIGHT OR PENDULOUS CHARACTERISTIC
F —GRAVITATIONAL FORCE

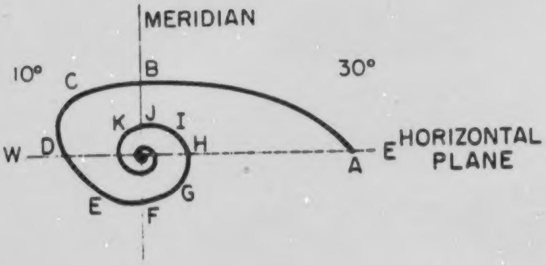
77.208

Figure 12-15.—Damping arrangements of the pendulous compass.


V
H-H'
S
N
FS
FN
F
FW
V'
A
B
C
D
FS-FORCE EXERTED BY OIL IN SOUTH TANK
FN-FORCE EXERTED BY OIL IN NORTH TANK
FW-FORCE EXERTED BY PENDULOUS WEIGHT
F-RESULTANT FORCE

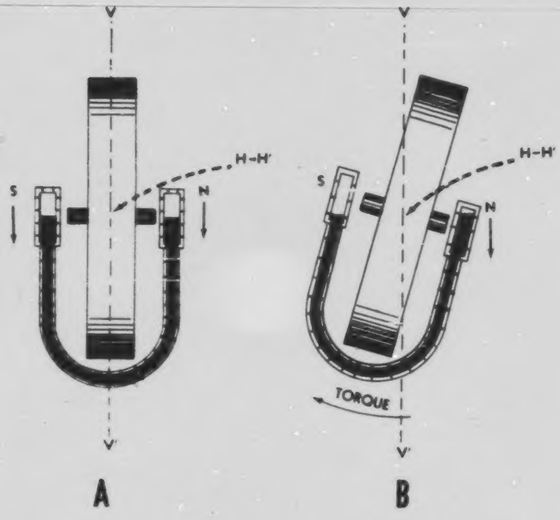
77.209
Figure 12-16.—Action of damping tanks.

oil has built up in the north tank so that the effect of the weight has been reduced. The length of the arrows indicates the magnitude of the force that is being exerted.



77.210
Figure 12-17.—Path followed by the north axle of a damped pendulous compass.

Starting with the compass displaced 30° to the east of the meridian and level (point A, fig. 12-17) the earth's rotations will cause the north axle to rise. This causes the pendulous weight to become elevated, the north axle up. This will produce a torque about the horizontal axis causing precession about the vertical axis to the west; however, due to the elevation of the north axle, it will cause the north tank to be elevated. This will cause a transfer of oil to the south tank. This transfer of oil to the south tank will be very slow because of the restriction in the connecting line and will not have much effect at the beginning. As time goes on however the oil accumulating in the south tank produces a torque about the horizontal axis opposing the torque produced by the pendulous weight making the net torque less than that produced by the pendulous weight above. The rate of precession will be less because there is now less torque causing precession. The north axle of the compass will continue to rise as long as it remains east of the meridian so that the pendulous weight will always exert enough torque to cause it to reach the meridian (point B, fig. 12-17). It cannot remain on the meridian however, because at this time it has maximum tilt, therefore maximum rate of precession. As the north axle of the compass crosses the meridian to the west, the earth's rotation will now cause the north axle to fall. This action further reduces the effect of the pendulous weight. As oil has been transferring to the south tank all this time because of the elevation of the north axle, a point is soon reached at which the torque produced by the oil ballistic is exactly equal and opposite to the torque produced by the pendulous weight. At this time the net torque about the horizontal axis is zero (point C, fig. 12-17). Therefore precession to the west ceases; however, the north axle of the compass (being west of the meridian) continues to fall due to the earth's rotation further reducing the torque produced by the pendulous weight. The torque produced by the oil ballistic is now greater than that produced by the pendulous weight and causes precession to the east even though the axle has not yet become level. As the north axle becomes level (point D, fig. 12-17) there is still an excess of oil in the south tank due to the restriction in the oil line. This excess of oil in the south tank causes it to continue to precess to the east, and the north axle continues to fall due to the rotation of the earth, elevating the south axle. The pendulous weight now produces a torque about the horizontal axis that also causes precession to the east. At this time the oil ballistic and pendulous weight are exerting torques that are aiding each other. As the south axle is now elevated, however, oil will be transferring to the north tank until a point is reached where there is equal oil in both tanks (point E, fig. 12-17). Precession continues to the east because of the torque produced by the pendulous weight. The south axle being elevated causes oil to continue to transfer to the north tank. This action produces an excess of oil in the north tank, causing a torque about the horizontal axis opposing that torque produced by the pendulous weight. As long as the north axle remains west of the meridian however, it will continue to fall, producing enough torque to cause it to reach the meridian (point F. fig. 12-17). At this time there is maximum tilt and maximum rate of precession, therefore, it cannot remain on the meridian. The north axle of the compass is now east of the meridian and will rise due to the earth's rotation further reducing the effect of the pendulous weight. As oil has been accumulating in the north tank during this time, a point is soon reached at which the torque produced by the oil ballistic is exactly equal and opposite to that produced by the pendulous weight. The net torque about the horizontal axis is now zero and precession to the east ceases (point G, fig. 12-17). The north axle continues to rise due to the earth's rotation further reducing the effect of the pendulous weight. The oil ballistic is now producing a greater torque than the pendulous weight and causes precession to the west even though the north axle is not yet level. When the north axle becomes level (point H, fig. 12-17), there is still an excess of oil in the north tank because of the restrictor in the connecting line which causes the compass to continue to precess to the west. As the north axle becomes elevated due to the earth's rotation, it raises the pendulous weight to the north which produces a torque about the horizontal axis that also causes precession to the west. The torques produced by the pendulous weight and the oil ballistic now aid each other. As the N-axle is now elevated, oil will transfer to the S-tank. A point is soon reached at which there is equal oil in both tanks (point I, fig. 12-17). Precession continues to the west due to the pendulous weight, and oil continues to transfer to the south tank which now produces a torque about the horizontal axis opposing the torque produced by the pendulous weight. The north axle will continue to rise as long as it remains east of the meridian. As it reaches the meridian it has maximum tilt and therefore maximum rate of precession and therefore cannot remain on the meridian (point J fig. 12-17). This action continues for about 2 1/2 oscillations at which time the compass has settled and is on the meridian.



77.201
Figure 12-18.—Action of a mercury ballistic.

Because of the restriction of the flow of oil, the oil flow of the damping tanks always lags behind the tilt of the rotor. This lag makes the oil ballistic useful as a damping device because the ballistic permits the weight of the oil to act at just the right time to oppose the oscillations away from the meridian.

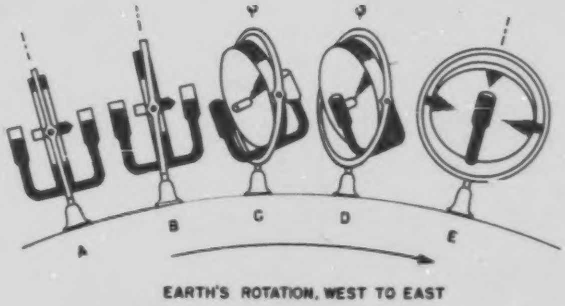
NONPENDULOUS METHOD

The method of controlling the gyro axle attitude in Sperry gyrocompasses is by a mercury ballistic that is balanced about its mounting axis so as to be nonpendulous until the mercury flows when the gyro tilts.

Mercury Ballistic

In its simplest form, the mercury ballistic consists of two mercury-containing reservoirs, one mounted at each end of the rotor axle. The two reservoirs are connected by a pipe so that the mercury is free to flow from one reservoir to the other, as shown in figure 12-18.

When the axle is level (fig. 12-18A), each reservoir contains the same amount of mercury, each weighs the same, and each exerts the same downward force on its end of the axle. Therefore, no torque is produced about any axis. When the axle is tilted, even slightly (fig. 12-18B), mercury runs through the connecting tube from the higher container to the lower container. The amount of mercury in the two tanks is no longer equal. The lower tank is heavier because it contains more mercury. Therefore, the lower tank exerts more force against its axle than does the upper tank, and produces a torque about axis H-H'. This torque which seemingly tends to increase the tilt, instead, causes precession about the vertical axis, V-V'.



77.202

Figure 12-19.—Elementary Sperry gyrocompass at the Equator.

The rotor in this gyrocompass spins counterclockwise when viewed from the south end of the axle. When the north end is low, the excess mercury in the north tank exerts a downward pressure on the north end of the axle and causes precession to the east, or clockwise. When the north end is high the excess mercury in the south [illegible] exerts a downward pressure on the south end of the axle and causes precession to the west, or counterclockwise.

As you have learned, when the north end of the rotor axle is east of the meridian, the earth's rotation causes it to rise. When a mercury ballistic is added to the gyroscope, the elevation of the north axle produces a torque about the horizontal axis that causes counterclockwise, or westerly, precession. When the north end of the axle is west of the meridian, the earth's rotation causes it to drop. A low north axle causes the mercury ballistic to exert a torque about the horizontal axis that gives clockwise, or easterly precession.

If this gyroscope with its mercury ballistic is set on the Equator with the axle pointing to the east of the meridian and with the rotor spinning counterclockwise (fig. 12-19A) the north end of the axle tilts upward because the earth rotates under it. When this tilt occurs mercury flows from the north to the south tank, and the south tank becomes the heavier. The south tank applies a torque about the horizontal axis (fig. 12-19B). This torque results in a precessional motion about the vertical axis toward the meridian and the west. Because the earth is constantly turning, the gyroscope continues to tilt upward, more mercury flows to the south tank, and the torque about the horizontal axis gradually increases with a corresponding increase in the precession about the vertical axis (fig. 12-19 C&D). This upward tilting continues until the gyroscope axle is on the meridian (fig. 12-19E). The south tank contains more mercury than the north tank, and the gyroscope is tilted upward its greatest amount. At this point the rate of precession is at its peak.

After the gyroscope axle crosses the meridian it begins tilting downward so that mercury flows from the south tank to the north tank. This transfer of mercury gradually reduces the torque about the south end of the axle with a corresponding gradual reduction in the rate of precession of the gyroscope about the vertical axis. When the gyroscope axle is once more level, it points to the west of the meridian, the mercury is distributed equally in both tanks, no torque is applied to either the north axle or the south axle, and precession ceases.

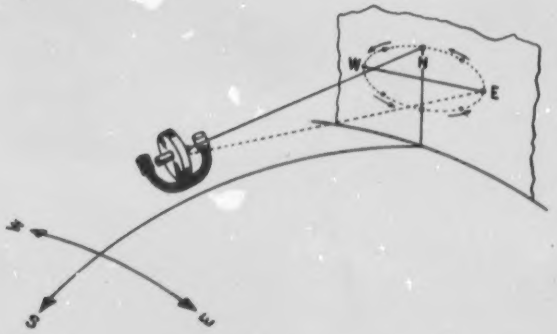
As the earth continues moving, the north end of the gyroscope axle tilts downward, and mercury flows into the north tank, which applies a torque to the north end of the spin axis. Hence, the direction of precession is reversed and is now toward the east. The downward tilt of the spinning axis continues, and the torque and rate of precession increase. By the time the gyroscope axle reaches the meridian, it has attained its maximum rate of precession again, but it now has a downward tilt. After the gyroscope passes the meridian, the rotation of the earth starts the north end of the gyroscope axle tilting upward. As this action occurs the torque about the north axle gradually diminishes to zero and the precessional motion about the vertical axis slows down until the gyroscope axle is once more horizontal and precession ceases. When the gyroscope axle becomes horizontal, the axle points in its original starting position. Figure

12-20 shows that the path followed by the north axle of the gyroscope has the shape of an ellipse. The gyroscope continues these oscillations indefinitely as long as the wheel is spinning.

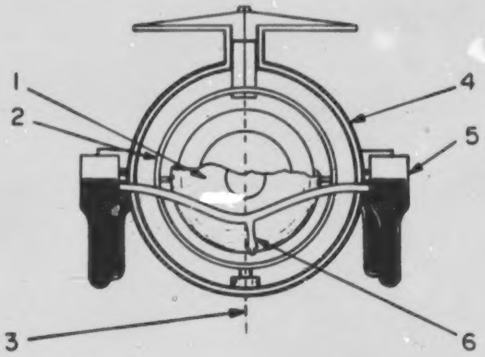
Oscillations are damped in this nonpendulous gyrocompass utilizing the mercury ballistic by employing a portion of the torque produced by the action of gravity upon the mercury ballistic to remove some of the tile given the rotor axle by the rotation of the earth.

In the previously described mercury ballistics, the tanks are attached directly to the bearings at the ends of the shaft. In the actual compass the ballistic is pivoted on studs and bearings on an outside ring, called the phantom ring, in such a way that its only point of contact with the gyroscopic element is through a connecting arm, or link, which bears against the bottom of the case in which the rotor spins (fig. 12-21). The rotor case corresponds to the inner ring of a gyroscope and holds the bearings on which the axle turns.

If the point of connection between the mercury ballistic and the rotor case is in the line of the vertical axis the only torque that can be exerted by the mercury ballistic is about the horizontal axis, and the resulting precession is only about the vertical axis. Thus, the compass would oscillate only back and forth across the meridian. However, if this point of connection between the ballistic and the rotor case is set a fraction of an inch to the east of the vertical axis (fig. 12-21), the force exerted by the mercury ballistic is applied about both the horizontal and the vertical axes, and torque is exerted about both the axes. Precession then results about both the vertical and the horizontal axes. Precession about the horizontal axis is much slower than precession about the vertical axis because the point of connection is offset from the vertical axis only a small amount.



77.203
Figure 12-20.—Undamped period of the Sperry compass at the Equator.



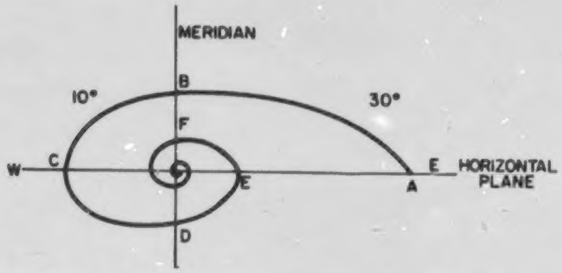
1. ROTOR CASE 2. VERTICAL RING

3. CENTER LINE 4. PHANTOM ELEMENT

5. MERCURY BALLISTIC 6. OFFSET ARM CONNECTION

77.206
Figure 12-21.—Elements of a nonpendulous compass.

With the compass displaced 30°E of the meridian and level (point A, fig. 12-22) the earth's rotation will cause the north axle to rise. When the north end rises it causes a transfer of mercury to the south tank. Gravity action on this excess of mercury in the south tank causes torques to be exerted about both the horizontal and vertical axes. The torque about the horizontal axis causes precession of the north end of the gyrocompass axle to the west about the vertical axis. The torque about the vertical axis causes precession of the north end of the gyrocompass axle downward about the horizontal axis. At this time the precession about the horizontal axis opposes apparent rotation about the horizontal axis. The precession about the vertical axis will cause the compass to precess to the meridian. However, the compass cannot remain on the meridian (point B, fig. 12-22), because at this time it has its maximum tilt and therefore maximum rate of precession about the vertical axis. As the gyro precesses past the meridian, the



77.207
Figure 12-22.—Path followed by the north axle of a damped nonpendulous compass.

direction of apparent rotation about the horizontal axis and the direction of precession about the horizontal axis are now both downward. This action causes the gyro to become level (point C, fig. 12-22). When the axle becomes level, precession ceases as there are no torques being applied by the mercury ballistic. If the proper (correct) torques have been applied, the compass would be only 10°W of the meridian, reducing the oscillation by 66 2/3 percent. As the earth continues to rotate, however, the compass will not remain level. Apparent rotation about the horizontal axis causes the north axle to tilt downward. This action causes a transfer of mercury to the north tank. Gravity action on this excess of mercury in the north tank will produce torques about both the horizontal and vertical axes. The torque about the horizontal axis will cause precession about the vertical axis, the north end moving toward the east. The torque about the vertical axis will cause precession about the horizontal axis, the north end moving upward, again opposing apparent rotation about the horizontal axis. The precession about the vertical axis will cause the gyro to precess to the meridian (point D, fig. 12-22). It cannot remain in the meridian however because at this time it has maximum tilt, therefore maximum, rate of precession, causing the gyro to precess past the meridian. Now that the north axle is again east of the meridian, the apparent rotation about the horizontal axis and the direction of precession about the horizontal axis both cause the north axle to become level (point E, fig. 12-22) more quickly. At this time the compass would be approximately 3 1/3° east of the meridian. This damping action would continue for approximately 2 1/2 oscillations, and the compass would then settle on the meridian.

COMPARISON CURVE

For comparison, the oscillation curve of an undamped compass and the oscillation curves of a damped nonpendulous and pendulous compass are shown in figure 12-23. Note that the damped period for both compasses is somewhat longer than the undamped period and that the damped period of the pendulous compass is longer than that of the nonpendulous.

The amount by which each successive swing past the meridian is reduced by the damping device is not the same for all swings. In the pendulous compass it is less on the first swing than on the following swings. In the nonpendulous compass it is greater on the first swing than on succeeding swings. The average amount by which successive oscillations are reduced is called the percentage of damping or the damping factor. It is about 70 percent for both pendulous and nonpendulous type compasses.

SPERRY MK 11 MOD 6 GYROCOMPASS

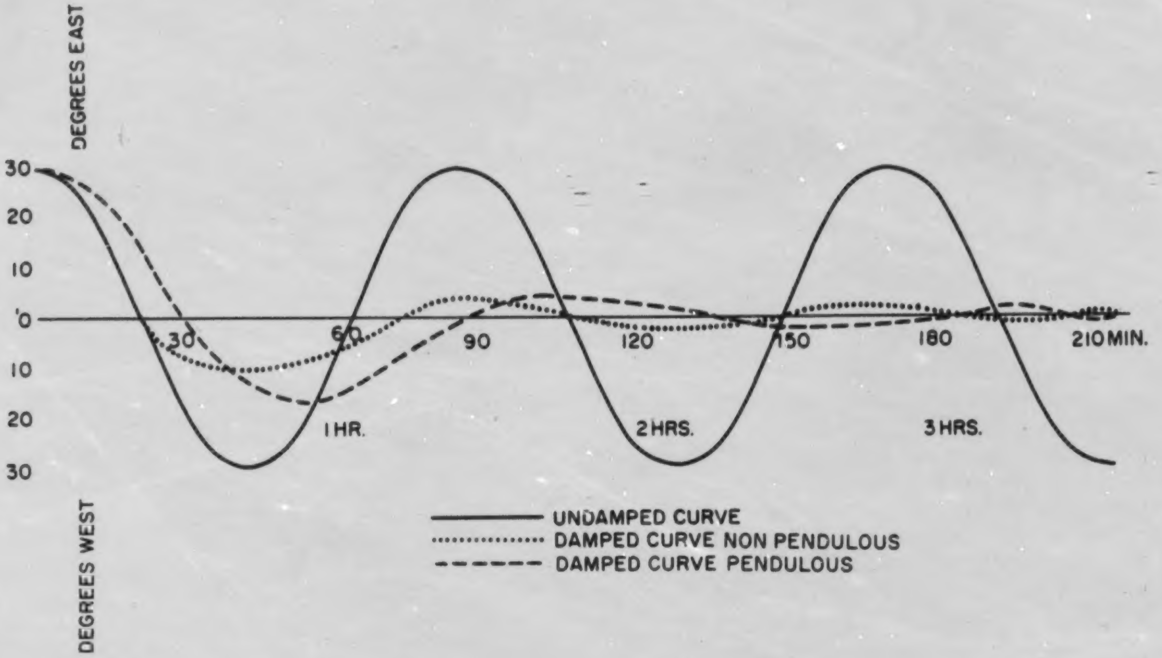
The Sperry Mk 11 Mod 6 gyrocompass is used principally on destroyers. The complete system consists of the master compass, the control system, alarm system, followup system, and the transmission system. The master compass includes five major components: (1) sensitive element, (2) mercury ballistic, (3) phantom element, (4) spider, and (5) binnacle and gimbal rings. The binnacle and gimbal rings enclose and support the other four major components (fig. 12-24).

SENSITIVE ELEMENT

The sensitive element (fig. 12-25) is the north-seeking element of the master compass. It consists of the gyro unit, vertical ring, compensator weights, followup indicator, and suspension.

Gyro Unit

The gyro unit provides the directive force for the sensitive element that makes the compass north-seeking. The unit consists of the rotor and case (fig. 12-26). The gyro rotor is 10 inches in diameter, 4 1/2 inches wide, and weighs approximately 72 pounds. It is machined and balanced to rotate on special ball bearings at a normal speed of 11,000 rpm.



77.211

Figure 12-23.—Oscillation curves of damped and undamped compasses.

The gyro case includes a 3-phase, double-stator winding, one stator being mounted in each half of the case.

The case is made airtight and the rotor operates in a vacuum (26 to 30 inches of mercury) to reduce the friction caused by air resistance. A vacuum gage (not shown) is mounted near the top of the north half of the case to indicate the degree of vacuum.

A spirit level (gyro case level in fig. 12-25) is mounted on the lower part of the north side of the case to indicate the tilt of the rotor.

A small window (not shown) is provided in the south half of the case through which the spinning rotor can be observed during starting.

Vertical Ring

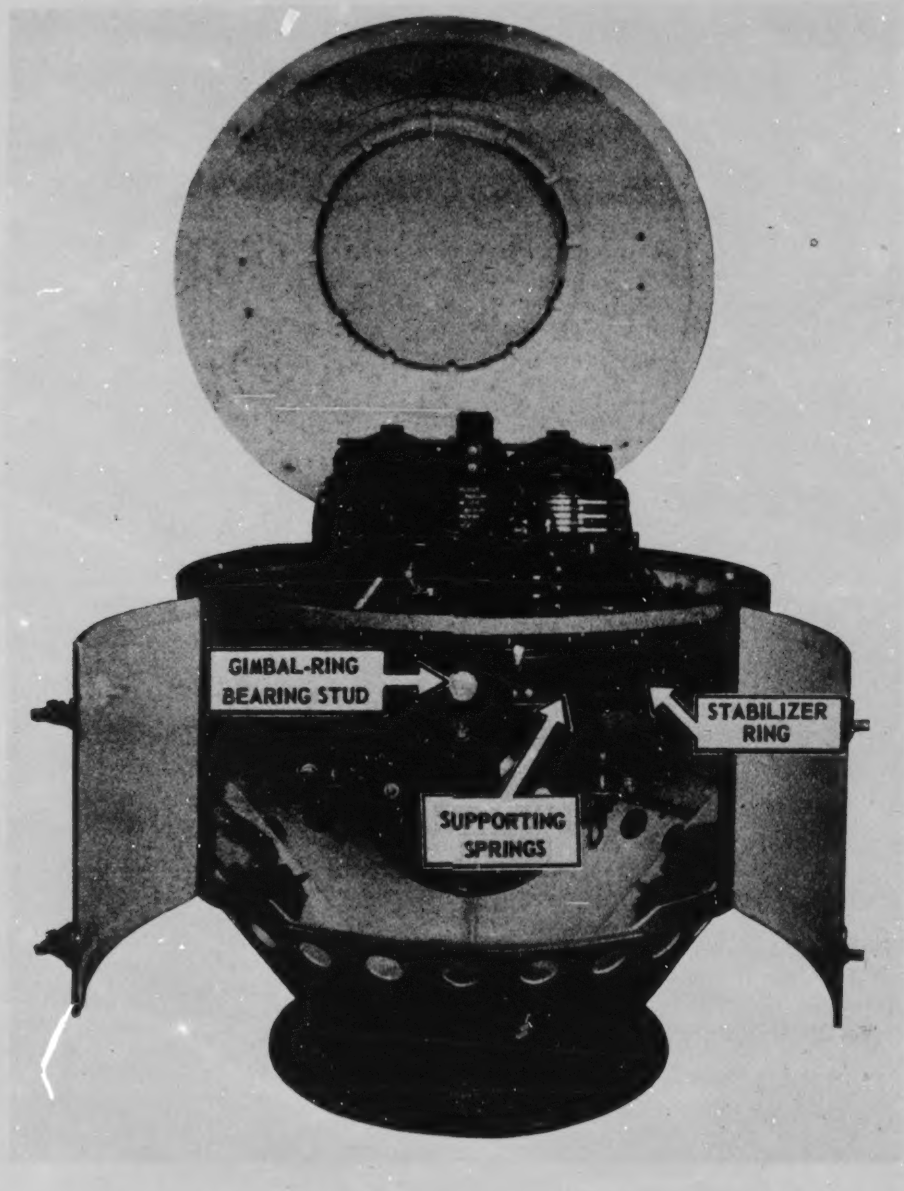
The vertical ring (fig. 12-25) is attached to a wire suspension from the head of the phantom element. The phantom ring is concentric with the vertical ring and surrounds the entire sensitive element. It is kept in alignment with the vertical ring, while the compass is in operation, by the action of the followup system, discussed later.

An upper and a lower guide bearing prevent the vertical ring from moving laterally within the phantom ring.

The upper guide bearing has its outer race secured in the phantom ring. The inner race is formed by the lower stud of the suspension. The lower guide bearing has its outer race secured in the bottom of the vertical ring. The inner race is formed by a vertical stud that projects upward from the bottom of the phantom ring.

The gyro case lock at the bottom of the case prevents the gyro case from tilting about its horizontal axis when the compass is not operating. This latch should be disengaged only when the rotor is running at normal speed. It is located on the lower part of the south side of the vertical ring. The vertical ring lock keeps the vertical ring in line with the phantom ring when the compass is not operating. This lock prevents the wire suspension from acquiring a permanent set which would affect the settling point of the compass.

The compensator weights (fig. 12-25) are supported by two frames that are attached to the



40.35
Figure 12-24.—Sperry Mk 11 Mod 6 gyrocompass.

vertical ring. These frames project out beyond each end of the rotor axle. The weights can be moved in or out along their studs. The function of the weights is to provide an even distribution of the weight of the gyrocompass about the vertical axis.

The armature of the signal pickoff or followup transformer is attached to an arm that protrudes horizontally from the upper part of the south compensator-weight from (fig. 12-25).

The followup indicator (not shown) indicates the position of the phantom element with relation

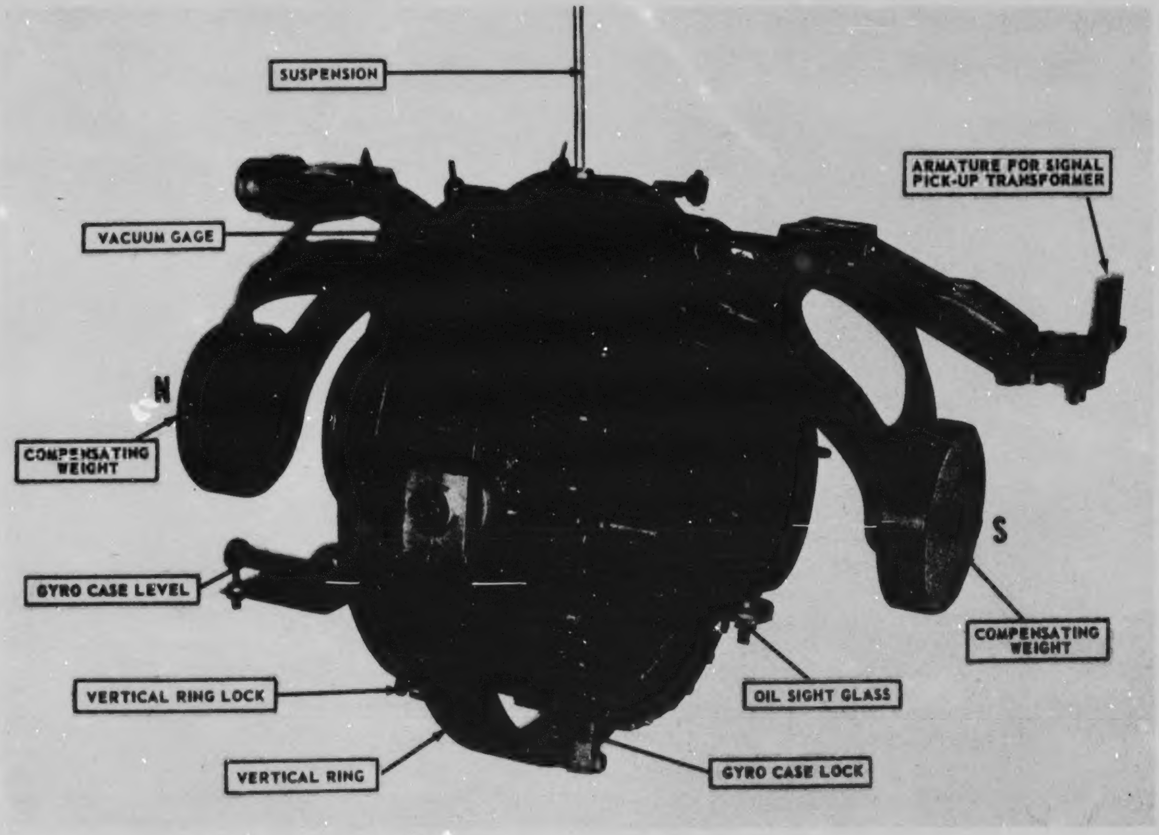
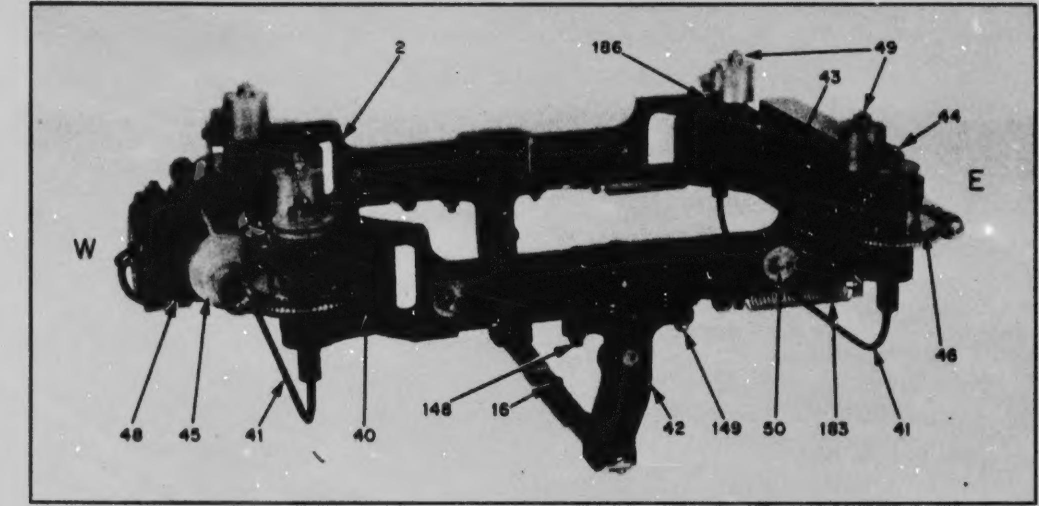

SUSPENSION
ARMATURE FOR SIGNAL PICK-UP TRANSFORMER
VACUUM GAGE
N
COMPENSATING WEIGHT
S
GYRO CASE LEVEL
COMPENSATING WEIGHT
VERTICAL RING LOCK
OIL SIGHT GLASS
VERTICAL RING
GYRO CASE LOCK

Figure 12-25.—Sperry Mk 11 Mod 6 sensitive element. 40.30

STATOR
LAMINATED SQUIRREL-CAGE ROTOR

Figure 12-26.—Sperry Mk 11 Mod 6 gyro unit. B, rotor; A and C, case. 40.31



2	MERCURY BALLISTIC FRAME	46	LATITUDE SCALE
16	OFFSET CONNECTION BEARING STUD	48	DAMPING ELIMINATOR MAGNET
40	MERCURY RESERVOIRS	49	NON-PENDULOUS BALANCING WEIGHTS
41	MERCURY TUBE	50	HORIZONTAL BALANCING WEIGHTS
42	CONNECTION ARM	148	NO-DAMPING ADJUSTMENT SCREW
43	MERCURY BALLISTIC SUPPORT STUD	149	DAMPING ADJUSTMENT
44	MERCURY RESERVOIR SUPPORT STEM	183	MAGNET LINK SPRING
45	LATITUDE SETTING THUMB WHEEL	186	LEVELING SCREW HOLES

40.32

Figure 12-27.—Sperry Mk 11 Mod 6 mercury ballistic.

to the sensitive element. This indicator consists of a scale and a pointer. The scale is attached to the phantom element below the spider table and the pointer is attached to the north compensator weight frame. The scale is calibrated in degrees with the center marked "0". Thus, a misalignment between the phantom element and sensitive element is indicated in degrees.

The suspension (fig. 12-25) suspends the entire sensitive element from the phantom element. It consists of a bundle of small steel wires secured at the upper end to a support stud and at the lower end to a guide stud. A nut and check nut secures the support stud to the phantom element, and provides a means to adjust the sensitive element vertically. The guide stud passes through a hole in the upper part of the vertical ring and is clamped to the ring by a nut. This stud also serves as the inner race of the upper guide bearing of the ring.

MERCURY BALLISTIC

The mercury ballistic (fig. 12-27) is that group of parts which applies the gravity controlling force to the gyro unit and makes it north-seeking. It consists of a rigid frame supported on bearings in the phantom ring. These bearings are in line with the horizontal case bearings in the vertical ring so that the mercury ballistic is free to tilt about the east-west axis of the sensitive element.

The frame supports a mercury reservoir in each of its four corners. The N and S reservoirs on the east side of the compass are connected by a U-shaped tube and the N and S reservoirs on the west side are similarly connected. The gravity controlling force of the mercury ballistic is applied to the bottom of the gyro case through an adjustable offset bearing stud mounted on the ballistic connection arm.

The connection bearing is offset to the east from the vertical axis by a short distance to provide the damping adjustment. When it is desired to eliminate damping, a solenoid (damping eliminator magnet) is energized by an automatic damping eliminator switch (discussed later) that attracts a plunger which moves the pivoted connection arm until the connection bearing is in line with the vertical axis of the gyro. In addition, each mercury reservoir is offset from its supporting stem so that each can be rotated around its stem through an arc of about 110° in order to vary the lever arm of each tank. Thus the period of an undamped oscillation of the gyrocompass is maintained constant in all latitudes by adjustment of the mercury reservoirs. This adjustment is referred to as the ballistic latitude adjustment.

PHANTOM ELEMENT

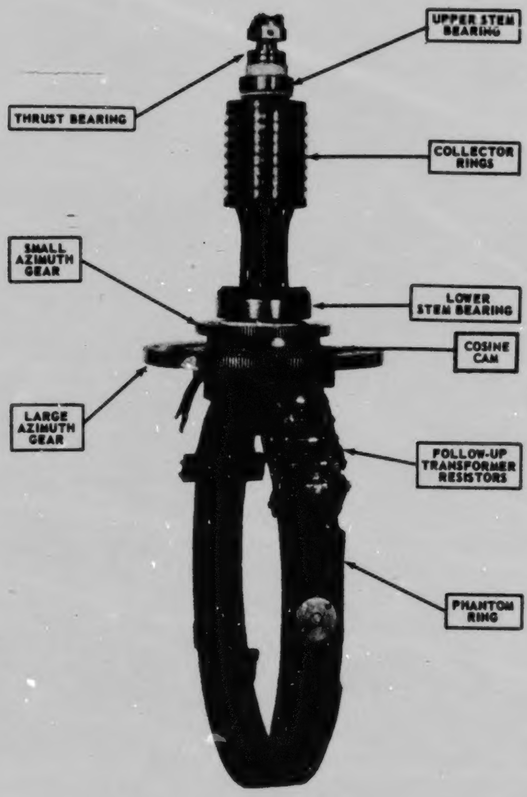
The phantom element (fig. 12-28) is a group of parts that acts to support the sensitive element. It consists essentially of a hollow cylindrical stem that projects radially from the phantom ring. The stem is mounted in the spider and extends down from the central hub of the spider table.

The phantom element supports the sensitive element by means of the suspension (wire bundle). The phantom element has no north-seeking properties of its own, however it does continuously indicate north, because it is made to follow all movements of the sensitive element by the action of the followup system.

A thrust bearing on the top of the stem (fig. 12-28) rests in the hub of the spider table and supports the weight of the phantom and sensitive elements. The upper and lower stem bearings keep the stem in alignment with the vertical axis of the spider but permit the phantom element to rotate about its own vertical axis.

The phantom ring also carries bearings that support the mercury ballistic. The axis of these bearings coincides with the axis of the horizontal bearings of the gyro case. Collector rings are mounted on the phantom stem below the upper stem bearing to connect the various electrical circuits from the fixed to the moving parts of the compass. The large and small azimuth gears are included in the azimuth followup mechanism (to be discussed later).

An eccentric groove called the cosine cam is cut into the upper surface of the large azimuth gear. The cosine cam is associated with the speed and latitude corrector mechanism.



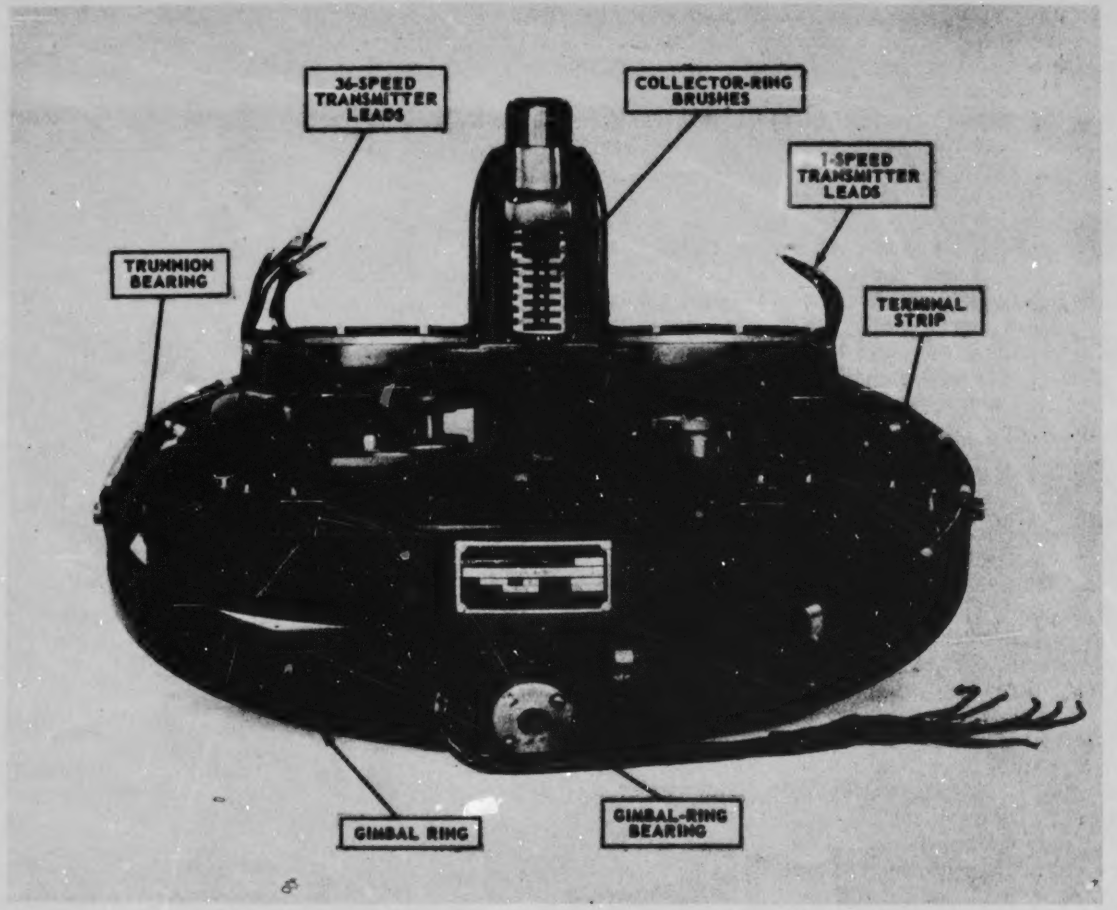
40.33

Figure 12-28.—Sperry Mk 11 Mod 6 phantom element.

SPIDER

The spider (fig. 12-29) is a circular table of cast aluminum alloy that supports the entire inner, or moving, member of the compass by means of the hub on which the thrust bearing that supports the phantom element rests. The spider is supported in the inner, or cardan, ring of the two rings that comprise the gimbal system. A boss in the center of the table supports the thrust bearing and the upper and lower stem bearings.

The azimuth followup motor and the automatic damping eliminator switch are mounted on the forward side of the spider table. The speed and latitude correction mechanism and the auxiliary latitude corrector are mounted on the after side of the spider table. The 36-speed synchro


36-SPEED TRANSMITTER LEADS
COLLECTOR-RING BRUSHES
1-SPEED TRANSMITTER LEADS
TRUNNION BEARING
TERMINAL STRIP
GIMBAL RING
GIMBAL-RING BEARING

40.34

Figure 12-29.—Sperry Mk 11 Mod 6 spider.

transmitter is located on the port side and the single-speed synchro transmitter is located on the starboard side of the spider.

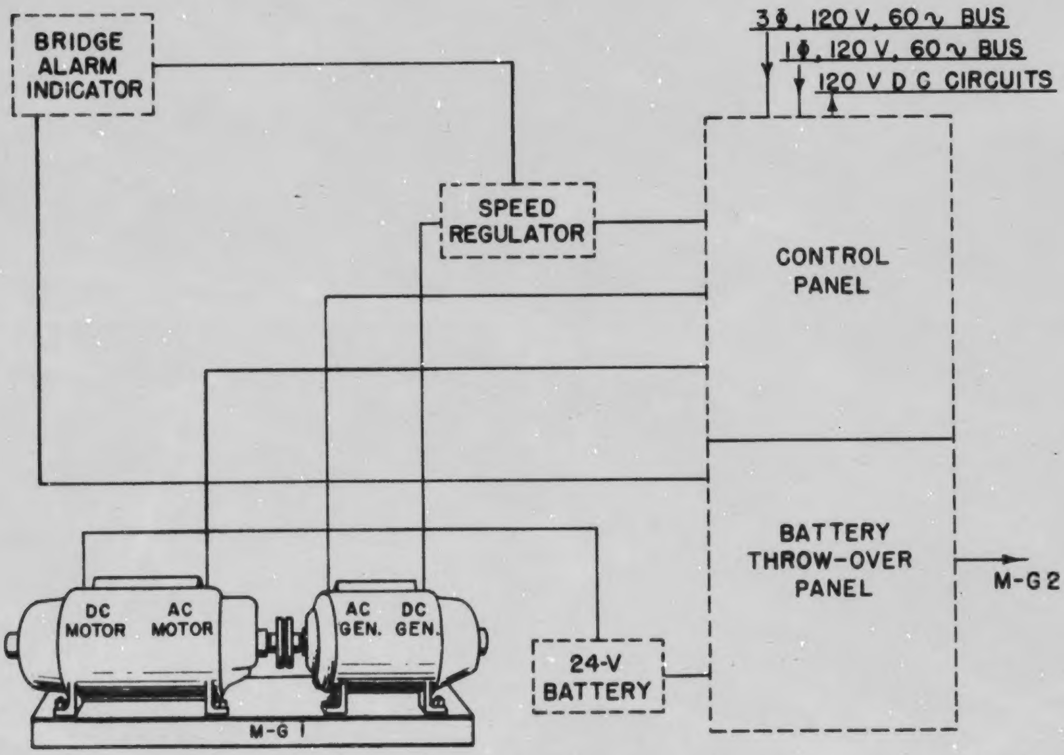
CONTROL AND ALARM SYSTEM

The Sperry Mk 11 Mod 6 gyrocompass control and alarm system consists of a motor-generator, speed regulator, control panel, battery throwover panel, and bridge alarm indicator, with the necessary apparatus for the operation and control of the master compass. The principal components of the system are illustrated in figure 12-30.

The gyrocompass drive system consists of the primary and emergency sources of power. The primary power source is the ship's 3-phase, 120-volt, 60-hertz supply and the emergency power source is the 24-volt battery.

Motor-Generator Sets

Two separate motor-generator sets are provided with each complete Sperry gyrocompass. Each set consists of an induction motor, a d-c emergency motor, an a-c generator, and a d-c generator (fig. 12-30). The induction motor and the d-c emergency motor are mounted on a common shaft in a single frame. The a-c generator and the d-c generator are also mounted on a common shaft in a single frame. The shafts



40.36

Figure 12-30.—Sperry Mk 11 Mod 6 gyrocompass control and alarm system.

of these two units are directly coupled together. Each motor-generator set is assembled as a complete unit and mounted on a single bedplate.

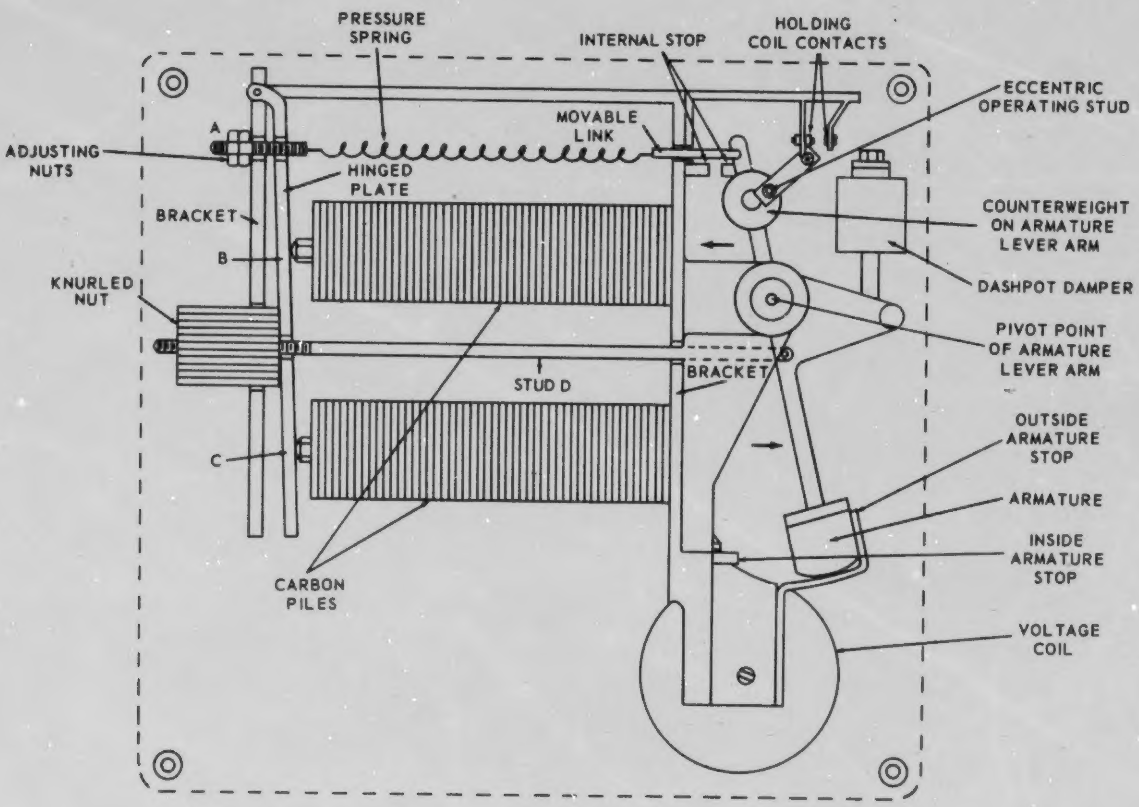
The induction motor is a 3-phase, 120-volt, 60-hertz, wound-rotor motor with slip rings. Under normal operating conditions, the induction motor drives the d-c motor, the a-c generator, and the d-c generator. It operates at a constant speed of 1460 rpm (necessary for the a-c generator to deliver a constant 3-phase output of 60 volts at 195 hertz), which is maintained constant by means of a speed regulator that compensates for a maximum of ±10% variations in the ship's primary power supply frequency.

The d-c motor is a shunt-wound machine. Under normal conditions of induction motor drive, the d-c motor operates as a self-excited d-c generator for charging the battery with a continuous-duty rating of 27 volts at 7 amperes.

Under emergency operating conditions because of failure in the ship's 3-phase supply to the induction motor, the d-c motor operates from the battery supply to drive the a-c and d-c generators. As a d-c motor, it has an intermittent-duty rating of 22.5 volts at 70 amperes.

The a-c generator is a 3-phase, 60-volt, 195-hertz, inductor type generator having 16 polar projections. Both the field and the armature are stationary. The 16 polar projections (inductors) are rotated continuously at approximately 1,460 rpm thereby varying the magnetic field flux through the armature windings and generating a-c voltages at a frequency of 195 Hz. The armature consists of a wye-connected, 3-phase winding, and the field consists of a single d-c winding. Slip rings are not required with this type of generator. The machine supplies power to drive the gyro rotor and to energize the amplifier and the followup system.

The d-c generator is a 120-volt, compound wound, interpole, self-excited generator. This


PRESSURE SPRING
INTERNAL STOP
HOLDING COIL CONTACTS
ECCENTRIC OPERATING STUD
MOVABLE LINK
A
ADJUSTING NUTS
HINGED PLATE
BRACKET
COUNTERWEIGHT ON ARMATURE LEVER ARM
B
DASHPOT DAMPER
KNURLED NUT
PIVOT POINT OF ARMATURE LEVER ARM
STUD D
BRACKET
OUTSIDE ARMATURE STOP
C
ARMATURE
INSIDE ARMATURE STOP
CARBON PILES
VOLTAGE COIL

40.38

Figure 12-31.—Speed regulator schematic.

machine supplies excitation for its own fields, the a-c generator field, and the azimuth-motor field. It also supplies d-c power for the damping eliminator, the azimuth-motor cutout relay the dead-reckoning equipment, and the voltage coil of the speed regulator.

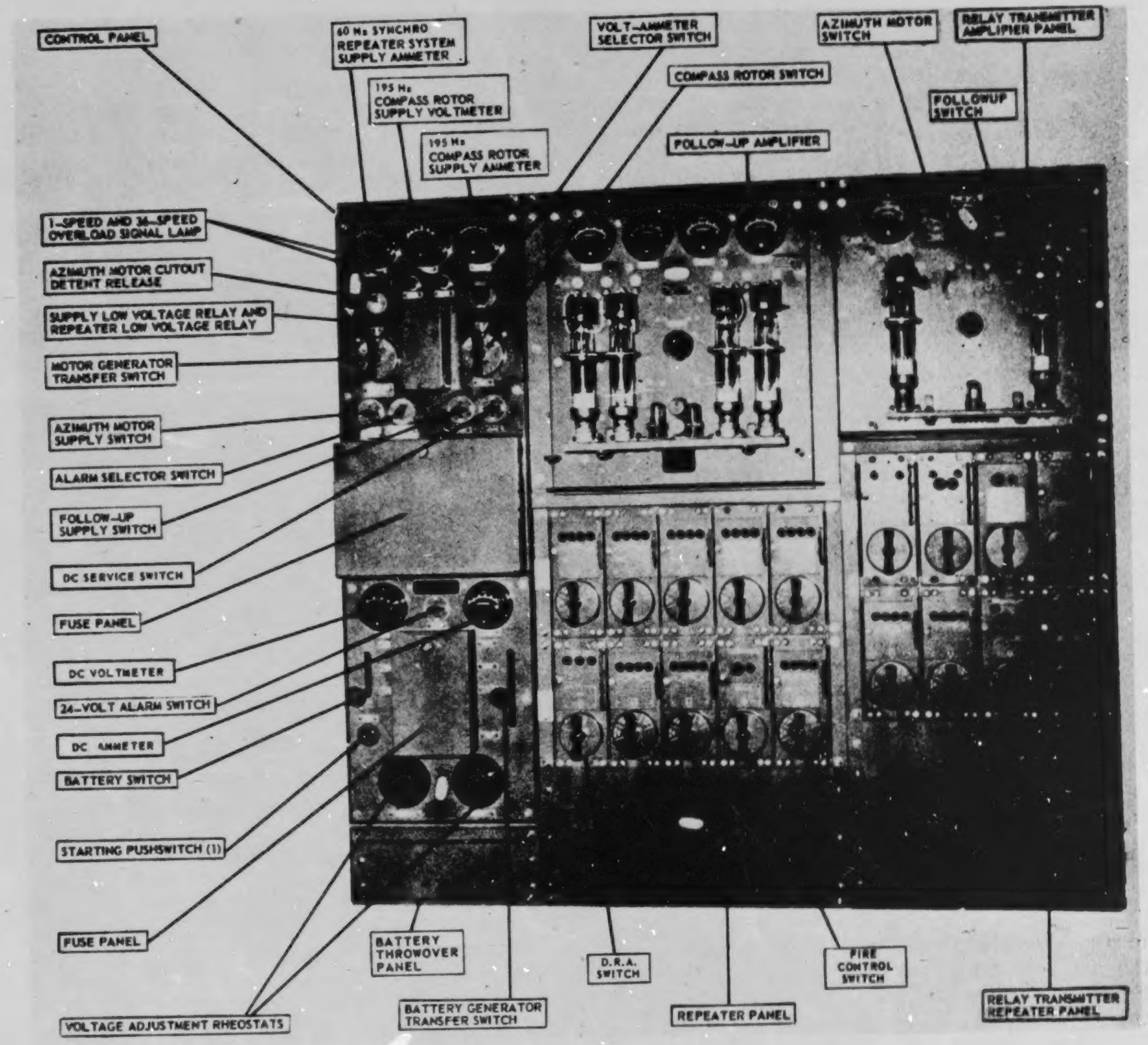
Speed Regulator

The speed regulator (fig. 12-31) is a separate unit located near the motor-generator sets. It compensates for variations in the ship's supply voltage or frequency to maintain the speed of the induction motor constant and thereby causes the a-c generator to deliver a constant output to drive the gyro motor. The same speed regulator is used for each of the two motor-generator sets because they are not operated simultaneously.

The speed regulator consists of a wye-connected, carbon-pile voltage regulator connected in the form-wound rotor circuit of the 3-phase induction motor by means of slip rings.

The actuating coil of the speed regulator is connected in a shunt circuit across the output terminals of the d-c generator. It, therefore, responds to changes in d-c output voltage occasioned by any changes in speed of the motor generator. The voltage coil attracts a spring-loaded pressure arm that varies the pressure on the carbon piles in accordance with any change in voltage across the coil.

If the ship's supply voltage or frequency increases, the induction motor-rotor current increases. This action causes a slight increase in the speed of the motor-generator. The consequent slight increase in d-c generator voltage causes the voltage coil of the speed regulator


CONTROL PANEL
60 Hz SYNCHRO REPEATER SYSTEM SUPPLY AMMETER
195 Hz COMPASS ROTOR SUPPLY VOLTMETER
195 Hz COMPASS ROTOR SUPPLY AMMETER
VOLT-AMMETER SELECTOR SWITCH
COMPASS ROTOR SWITCH
FOLLOW-UP AMPLIFIER
AZIMUTH MOTOR SWITCH
RELAY TRANSMITTER AMPLIFIER PANEL
FOLLOWUP SWITCH
1-SPEED AND 36-SPEED OVERLOAD SIGNAL LAMP
AZIMUTH MOTOR CUTOUT DETENT RELEASE
SUPPLY LOW VOLTAGE RELAY AND REPEATER LOW VOLTAGE RELAY
MOTOR GENERATOR TRANSFER SWITCH
AZIMUTH MOTOR SUPPLY SWITCH
ALARM SELECTOR SWITCH
FOLLOW-UP SUPPLY SWITCH
DC SERVICE SWITCH
FUSE PANEL
DC VOLTMETER
24-VOLT ALARM SWITCH
DC AMMETER
BATTERY SWITCH
STARTING PUSHSWITCH (1)
FUSE PANEL
VOLTAGE ADJUSTMENT RHEOSTATS
BATTERY THROWOVER PANEL
BATTERY GENERATOR TRANSFER SWITCH
D.R.A. SWITCH
REPEATER PANEL
FIRE CONTROL SWITCH
RELAY TRANSMITTER REPEATER PANEL

40.39

Figure 12-32.—Sperry Mk 11 Mod 6 gyrocompass switchboard.

to attract the spring-loaded arm. This action decreases the pressure on the carbon piles. The accompanying increase in rotor resistance restores the rotor currents to their normal value and checks the rise in speed and d-c generator output voltage.

A dashpot damper is connected in the pressure arm to prevent hunting when rapid changes occur in the voltage or frequency.

Compass Control Panel

The compass control panel is located at the upper left-hand section of the gyrocompass switchboard (fig. 12-32). The control panel is used to control and indicate the operating conditions of the master compass. The ship's 3-phase, 120-volt, 60-hertz power supply and the ship's single-phase, 120-volt, 60-hertz power supply are connected directly to terminals on the back of the compass control panel. The 3-phase, 120-volt, 60-hertz power supply is fed from these terminals on the control panel through the battery throwover relay on the battery throwover panel to the motor-generator transfer switch on the compass control panel. The switches and fuses necessary for these power supplies are included on the IC switchboards, but are not provided on the gyrocompass switchboard.

The a-c ammeters and an a-c voltmeters are mounted at the top of the control panel to indicate the operating conditions of the master compass. One ammeter indicates the 60-hertz alternating current supplied to the synchro repeater system by the master compass transmitter. The other ammeter and the voltmeter indicate the 195-hertz current and voltage supplied by the 3-phase a-c generator to the gyrocompass rotor.

The azimuth-motor cutout detent release, the single and 36-speed overload signal lamps, and the volt-ammeter selector switch are mounted just below the two ammeters and the voltmeter.

The azimuth motor cutout detent release is provided to reset the cutout after a fault has been cleared on the followup system.

The volt-ammeter selector switch is a 3-position rotary switch. The three switch positions provide for shifting the ammeter and voltmeter to any one of the three phases of the a-c gyro rotor supply to obtain current and voltage readings of the selected phase.

The motor-generator transfer switch and the compass rotor switch are mounted on the third row from the top.

The motor-generator transfer switch is a double-throw rotary switch provided for selecting either of the two motor-generators.

The compass rotor switch connects the 3-phase, 55-volt, 195-hertz power from the a-c generator to the gyrocompass rotor.

The azimuth-motor switch, the alarm selector switch, the followup supply switch and the d.c. service switch are located at the bottom of the control panel.

The azimuth-motor switch controls the rectified a-c supply circuit to the azimuth motor armature and the d-c supply to the azimuth-motor field.

The alarm selector switch is a rotary switch with four positions marked normal low frequency, repeater supply, and ship's supply. In the NORMAL position, the alarm bell sounds if the ship's supply or the repeater supply fail or if the supply voltage or frequency fall below a predetermined value. The alarm bell is silenced by turning the selector switch to the position indicating the trouble.

The followup supply switch is an on-off switch. In the ON position it energizes the followup panel from one phase of the 3-phase gyro supply, and heats the filaments of the amplifiers and rectifier tubes in the followup system.

If the followup switch is in the OFF position, the compass supply ammeter and voltmeter indicate the current and voltage to the gyro rotor only; whereas, if this switch is in the ON position, the meters will indicate the 195-hertz current voltage to both the gyro rotor and the followup panel.

The d-c service switch is the master switch for the 120-volt, d-c circuit. It supplies the damping eliminator circuits, azimuth-motor field, and azimuth-motor cutout relay coil.

The fuses for the compass control panel are within an enclosure located at the bottom of this panel.

Battery Throwover Panel

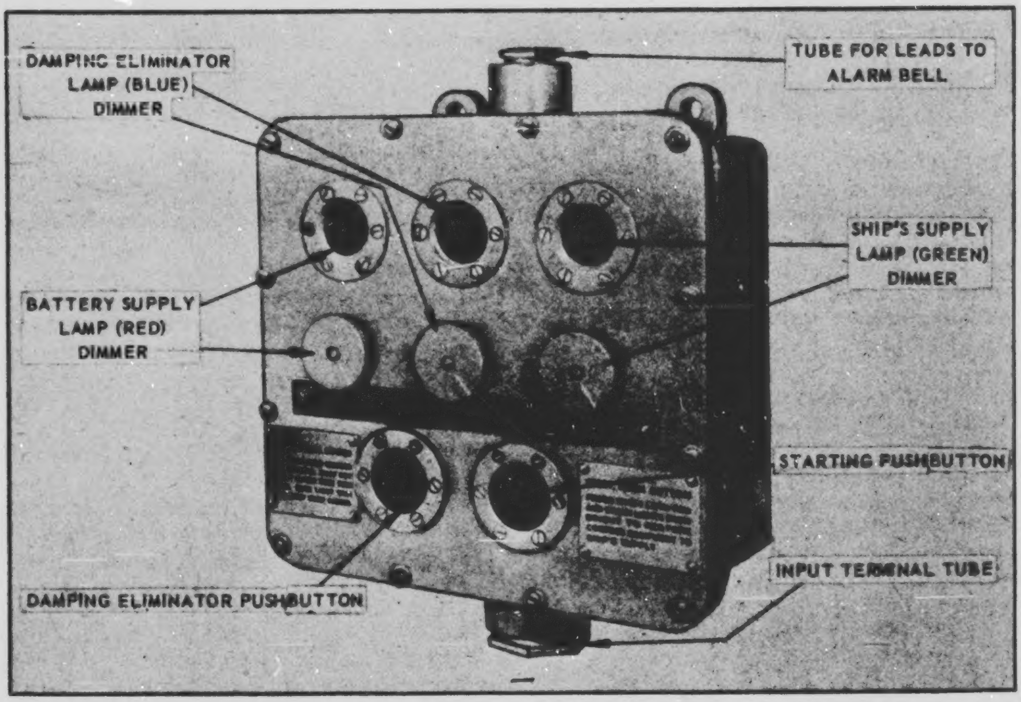
The battery throwover panel is located directly below the compass control panel (fig. 12-32). It is used to transfer automatically the gyrocompass circuits from the ship's 3-phase supply to the battery supply in the event of failure of the ship's supply. The 24-volt storage battery is normally connected to the battery-charging generator of the motor-generator set and floats on the line.

If the ship's 3-phase supply voltage or frequency drops below the predetermined value (±10% of the normal value), the movement of the pressure arm on the carbon piles of the speed regulator will open the battery throwever relay holding coil contacts, thereby deenergizing this relay. When this relay is deenergized, the (1) ship's 3-phase supply is disconnected from the motor-generator set, (2) battery is connected to the d-c motor (charging generator) as a primary power source so that the d-c motor becomes the prime mover for the motor-generator set, and (3) alarm bell rings.

When the ship's 3-phase power supply is restored, retransfer of the drive to the induction motor must be accomplished manually.

A 24-volt alarm supply switch and a battery voltmeter and ammeter are mounted at the top of the battery throwover panel.

The 24-volt alarm supply switch is a separate switch provided for cutting out the supply to the entire alarm system.



77.212

Figure 12-33.—Bridge alarm indicator.

The d-c ammeter and the d-c voltmeter connected between the battery switch and the battery-generator transfer switch, indicate the current and voltage respectively in the battery line.

The fuses for the battery throwover panel are within an enclosure located in the center of the panel.

The battery switch and the battery-generator transfer switch are located on the left-hand and the right-hand sides of the fuse enclosure, respectively.

The battery switch is a DPST lever-switch that connects the 24-volt battery supply to the battery throwover panel.

The battery generator transfer switch is a DPDT lever-switch that connects the battery to one or the other of the two battery generators.

The starting pushswitch is mounted below the battery switch. It is used to start the motor-generator and also to restore the circuit to the holding coil of the battery throwover relay after the system has been interrupted because of a failure of the ship's supply or low voltage and/or frequency.

An additional pushswitch in parallel with the starting pushswitch on the battery throwover panel is located on the bridge alarm indicator so that, if desired, the ship's power supply can be restored to the compass equipment from this station.

Two voltage adjustment rheostats, one for each of the battery generators, are mounted at the bottom of the panel. These rheostats are used to adjust the generator-field resistance to control the charging rate of the battery when the machine operates as a generator. The rheostats are cut out when the machine operates as a motor, and the resistance that is cut into the field by the battery throwover relay automatically increases the speed to the proper value.

Bridge Alarm Indicator

The bridge alarm indicator (fig. 12-33) is located in the pilot house. The indicator includes a red, a blue, and a green indicator lamp, a damping-eliminator pushswitch and a starting pushswitch. These components are enclosed within a metal case provided for bulkhead mounting. An external alarm bell is adjacent to this indicator.

The red indicator lamp in the battery supply indicates operation of the compass equipment from the 24-volt battery supply.

The blue indicator lamp is in the damping-eliminator circuit as a warning whenever the damping-eliminator coil is energized.

The green indicator lamp in the ship's a-c supply is lighted as long as the ship's supply is connected to the compass equipment.

Each indicator lamp is provided with a series variable resistor to control the intensity of illumination.

The starting pushswitch is in parallel with the pushswitch on the battery throwover panel as mentioned previously.

The damping-eliminator pushswitch is in parallel with the automatic damping-eliminator switch on the master compass and may be manually operated to energize the damping-eliminator coil and thus remove damping.

FOLLOWUP SYSTEM

The followup system includes the followup mechanism, the followup transformer, the azimuth motor, and the followup panel. The system functions to detect any misalignment between the phantom and sensitive elements and to drive the phantom element in the proper direction to restore alignment. Any misalignment between the phantom and sensitive elements results in a signal voltage output from the followup transformer. The amount of misalignment determines the magnitude of this signal voltage and the direction of misalignment determines its phase. The signal output from the followup transformer is amplified by a voltage amplifier and used to control the output of a power amplifier which operates the azimuth motor. The azimuth motor in driving the phantom element back into alignment with the sensitive element also drives the single and 36-speed synchro transmitters, and a lost motion device through the azimuth followup gearing mechanism (fig. 12-34).

The azimuth motor is a d-c motor having its field excited by the 120-volt d-c output from the motor generator. Its armature is connected in either one or the other of the two output rectifier circuits of the power amplifier. The direction of rotation depends upon which pair of output rectifiers is conducting when the plates of the voltage amplifiers are positive.

Followup Panel

The followup panel (fig. 12-32) is adjacent to the compass control panel. It includes a voltage amplifier and a power amplifier.

The voltage amplifier contains two twin triodes that amplify the weak signal voltage from the followup transformer. The power amplifier contains two pair of thyratron rectifiers that supply the azimuth motor armature current.

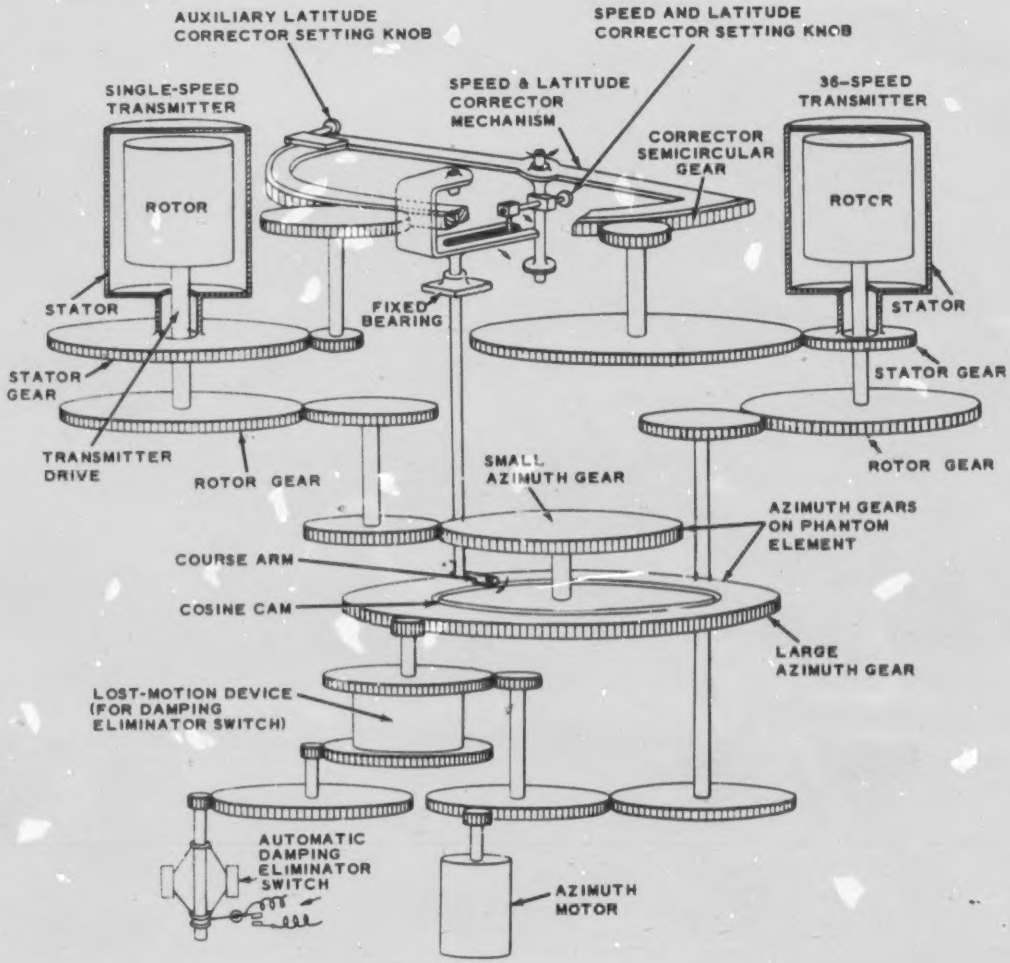
Followup Transformer

The followup transformer comprises three coils wound on an E-shaped laminated core (fig. 12-35). The primary coil (P) mounted on the center leg, is connected to the 3-phase 195-hertz compass rotor supply. One primary lead is connected to one phase through resistor R1 which limits the primary current to a few ma. The other primary lead ties to the common connection of phasing resistors R2 and R3 across the other two phases. This provides the proper phase relation between the followup signal voltage and the followup amplifier bias and plate voltages.

An armature carried on the sensitive element serves as a closing link in the double magnetic circuit of the followup transformer. The armature is positioned so that a small air gap is maintained between the armature and the transformer.

Secondary coils A and B on the outside legs of the transformer are connected in such a manner that the induced voltage in one leg is 180° out of phase with the induced voltage in the other leg. Small capacitors C connected across the secondary coils, are in parallel resonance with the coils at 195 hertz in order to obtain the maximum voltage across the coils at that frequency. To balance the voltage output of the secondary coils when the armature is centrally located, two fixed resistors (not shown) are connected across the capacitors.

The E-shape followup transformer is mounted on the phantom element and will move with a change in the ship's heading. The armature, however, is mounted on the sensitive element or the north-seeking part of the compass and does not move once the compass has settled on the meridian.


AUXILIARY LATITUDE CORRECTOR SETTING KNOB
SPEED AND LATITUDE CORRECTOR SETTING KNOB
SINGLE-SPEED TRANSMITTER
SPEED & LATITUDE CORRECTOR MECHANISM
36-SPEED TRANSMITTER
CORRECTOR SEMICIRCULAR GEAR
ROTOR
ROTOR
STATOR
FIXED BEARING
STATOR
STATOR GEAR
STATOR GEAR
TRANSMITTER DRIVE
ROTOR GEAR
SMALL AZIMUTH GEAR
ROTOR GEAR
AZIMUTH GEARS ON PHANTOM ELEMENT
COURSE ARM
COSINE CAM
LARGE AZIMUTH GEAR
LOST-MOTION DEVICE (FOR DAMPING ELIMINATOR SWITCH)
AUTOMATIC DAMPING ELIMINATOR SWITCH
AZIMUTH MOTOR

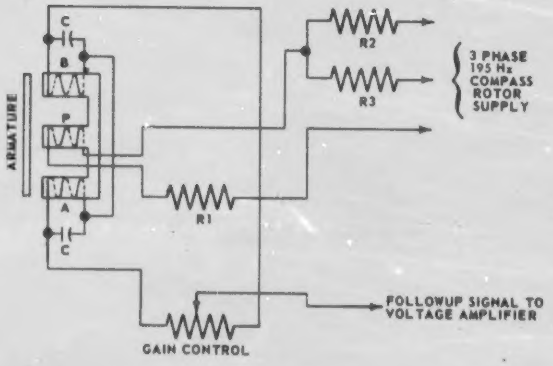
40.40

Figure 12-34.—Azimuth followup mechanism gearing.

With the compass settled on the meridian the phantom element is in alignment with the sensitive element, and the compass card will indicate the ship's heading. In this neutral position the voltages induced in the two secondaries of the followup transformer will be equal in amplitude, but differ in phase by 180 degrees. The output voltage, therefore, is zero and consequently no input signal is fed to the voltage amplifier.

However, when the followup transformer is moved either to the left or right, due to a change in the ship's heading, unequal fluxes pass through the transformer secondaries. As a result the secondary voltages become unbalanced. The resultant output voltage will be the vector sum of the two voltages and the phase of the output voltage will be the same as the phase of the secondary voltage having the greatest amplitude.

The phase of the output voltage is determined by the direction of the followup transformer movement and the voltage amplitude is determined by the amount of the movement.



77.213
Figure 12-35.—Simplified schematic diagram of followup transformer, Sperry Mk 11 Mod 6 gyrocompass.

Thus, the output signal from the followup transformer to the voltage amplifier is proportional in magnitude and phase to the amount and direction of the armature displacement or ship's movement.

TRANSMISSION SYSTEM

The Sperry Mk 11 Mod 6 gyrocompass transmission system provides a means of transmitting the readings of the master gyrocompass to a number of repeater compasses located at various stations in the ship. The single and 36-speed synchro transmitters (driven by the azimuth followup motor) control the movement of the repeater compasses that indicate the readings of the master compass at the remote stations.

The transmission system also includes the overload relays, repeater panel, relay transmitter repeater panel, relay transmitter, relay transmitter amplifier panel, differential alarm relay, and repeater compasses.

Transmitter Overload Relays

Two similar transmitter overload relays, mounted on the back of the compass control panel, provide a visual alarm when an overload occurs in the transmitter circuits. One relay is connected in the single-speed transmitter circuit, and the other relay is connected in the 36-speed transmitter circuits. The relay consists of three legs with a coil on each leg. Each coil is connected in series with a transmitter stator lead. An increase in the current through any or all of the coils above a critical value attracts the relay armature, causing it to move. This action closes a contact that lights a red signal lamp on the panel front, indicating trouble in the transmitter circuit. A stepdown transformer (115 volts to 7 volts) on the panel supplies the indicator lamp circuits.

Repeater Panel

The repeater panel (fig. 12-32) is below the followup panel. It comprises an assembly of rotary switches, and auxiliary equipment. Each switch with its associated fuses and overload indicating devices is assembled as a unit and can be withdrawn from the front of the panel for inspection and repair.

Each compass repeater switch is arranged to connect the circuits of two repeater compasses so that either one, or both, may be driven by the master compass transmitters.

Each repeater circuit is provided with an overload indicator, comprising a transformer and a neon lamp. The transformer has two primaries, which are connected in series respectively with two of the three secondary leads to the repeater. The transformer secondary is connected across the neon lamp. When the repeater is approximately alined with the transmitter, the very small current in the transformer primaries does not generate sufficient voltage across the secondary to illuminate the lamp. However, excessive current in the transformer primaries causes the lamp to glow and thus indicate trouble in this repeater circuit.

Associated with each of the repeater circuit switches are four fuses, access to which is through the hinged door just above the switch handle. Two of the fuses are in the primary circuit to the 1-speed repeater, and the remaining two are in the primary circuit to the 36-speed repeater.

The rotary type switch designated on the panel as the fire control switch is not provided with an overload alarm because connections are made from this switch to the fire control switchboard, which has an alarm for each circuit leaving the board. However, at the fire control switch on the repeater panel the two indicators are (1) a pilot lamp, connected across the a-c supply to this switch and therefore illuminated as long as this supply is available, and (2) a transformer and neon lamp arranged to indicate when one or both of the a-c supply fuses blow.

The rotary type switch designated on the panel as the dead reckoning analyzer switch is provided to operate the DRA from the underwater log transmitter and the 1-speed transmitter on the master compass. This switch also supplies single-phase, 120-volt, a-c power and 120-volt, d-c power necessary for the operation of the DRA. Each of these circuits is provided with two fuses. A neon lamp across each fuse in the d-c circuit is lighted when the fuse blows.

Relay Transmitter Repeater Panel

The relay transmitter repeater panel (fig. 12-32) is adjacent to the repeater panel. This panel and the repeater panel are arranged so that the repeater compasses can be connected to either the master-compass transmitter or to the relay transmitter.

The relay transmitter repeater panel includes eight rotary switches: a checking repeater switch, a fire control switch, a relay transmitter supply switch, an emergency navigation transfer switch, two compass repeater switches, and two radar mast (special) switches.

The checking repeater switch connects the gyrocompass-room checking repeater to either the master compass or to the relay transmitter. Two fuses are connected in series with the primary leads on the load side of the switch. Two transformer and neon-lamp overload indicators (one for each circuit) are connected in the transmitter secondary circuits to indicate an overload in these circuits.

Relay Transmitter

In order to actuate a number of repeater compasses without imposing this load directly on the compass transmitters, an intermediate instrument known as a relay transmitter is used. The relay transmitter (fig. 12-36) consists of a single-speed and a 36-speed synchro control transformer (CT), a commutator transmitter, a followup motor, and a reactor. These components are enclosed within a metal case provided for bulkhead mounting (fig. 12-36A).

The relay transmitter is synchronized with the master compass by means of the synchro control transformer followup motor, and relay-transmitter amplifier (fig. 12-36B). The controlling signal voltage from the master compass energizes the primaries of the control transformers. The output of the control transformers is fed to the amplifier, the output of which controls the followup motor. The followup motor drives a commutator type transmitter, the output of which energizes the repeaters, causing them to follow the master compass. The followup motor also drives the secondaries of the control transformers to the zero-voltage position, thereby synchronizing the relay transmitter with the master compass.

Relay Transmitter Amplifier Panel

The relay transmitter amplifier panel (fig. 12-32) is adjacent to the followup panel. It consists of a voltage amplifier and a power amplifier. The voltage amplifier receives the signal from the control transformers, and the output is fed to the power amplifier. The power amplifier provides the controlled power necessary to operate the followup motor in response to the signals from the voltage amplifier.

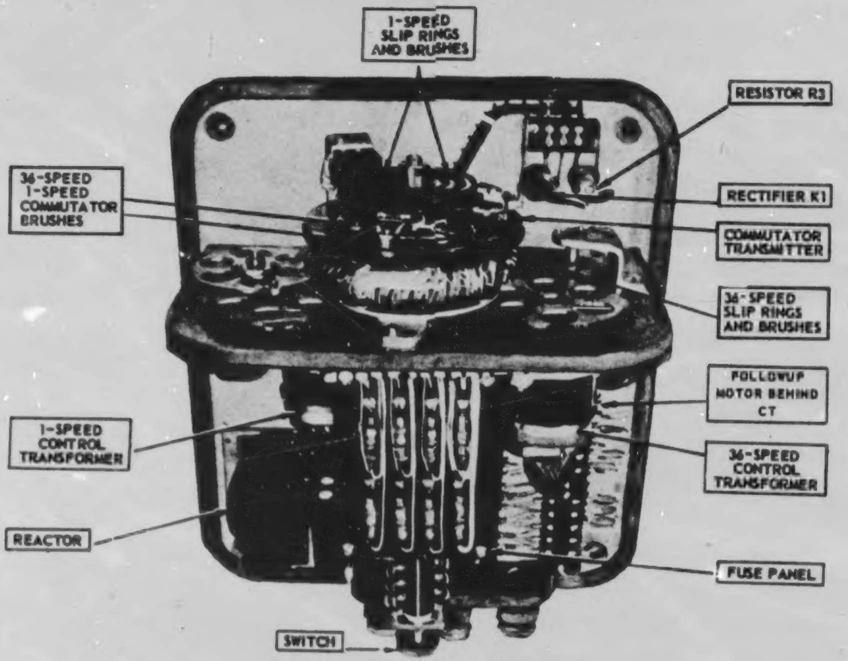
Differential Alarm Relay

The differential alarm relay (fig. 12-37) is a device for sounding an alarm whenever the relay transmitter loses synchronism with the master compass. The amount by which the transmitter is allowed to diverge, before the alarm is sounded, is adjustable from 0° to 2.5°.

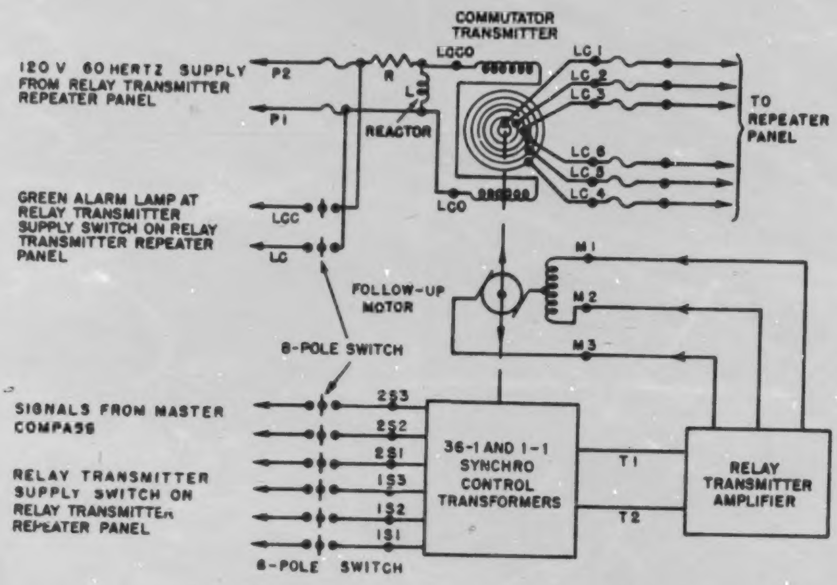
The device comprises a synchro differential receiver. The stator receives its signal from the 36-speed output of the relay transmitter; the rotor circuit receives its signal from the 36-speed transmitter at the master compass. As long as the two outputs are in agreement, the rotor remains at the neutral position. Failure of the relay transmitter to keep in synchronism causes the rotor to move from the neutral position to that amount corresponding to the divergence from synchronism.

A bakelite disk that has a metallic segment is mounted on the shaft of the differential receiver (fig. 12-37A). Two trolleys bear on the periphery of the disk. These trolleys are arranged so that rotation of the disk causes one trolley to contact the metallic segment. This action closes the 120-volt, a-c circuit to a relay (fig. 12-37B), which in turn, closes the 120-volt, a-c supply to the alarm bells located in the pilot house.

An 8-pole switch on the relay transmitter repeater panel is provided for disconnecting the differential synchro receiver and the alarm circuit (fig. 12-37B). The toggle switch disconnects only the alarm circuit.


1-SPEED SLIP RINGS AND BRUSHES
RESISTOR R3
36-SPEED 1-SPEED COMMUTATOR BRUSHES
RECTIFIER K1
COMMUTATOR TRANSMITTER
36-SPEED SLIP RINGS AND BRUSHES
FOLLOWUP MOTOR BEHIND CT
1-SPEED CONTROL TRANSFORMER
36-SPEED CONTROL TRANSFORMER
REACTOR
FUSE PANEL
SWITCH

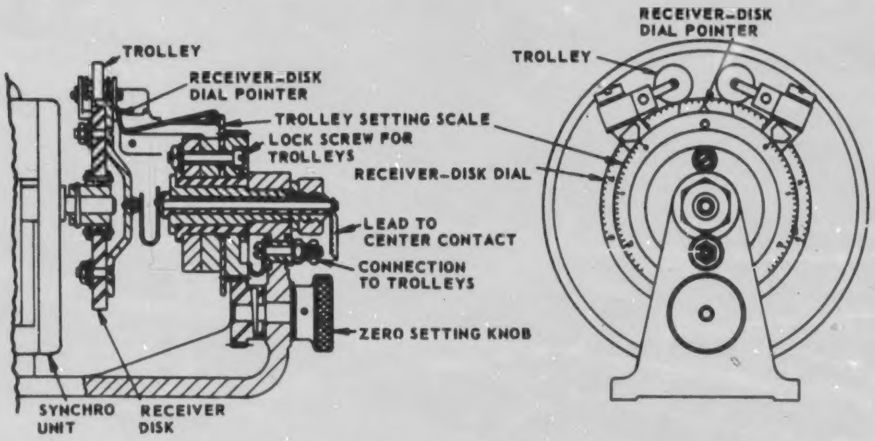
A. INTERNAL VIEW


COMMUTATOR TRANSMITTER
120 V 60 HERTZ SUPPLY FROM RELAY TRANSMITTER REPEATER PANEL
P2
P1
R
L
REACTOR
LCCO
LCO
LC 1
LC 2
LC 3
LC 6
LC 5
LC 4
TO REPEATER PANEL
GREEN ALARM LAMP AT RELAY TRANSMITTER SUPPLY SWITCH ON RELAY TRANSMITTER REPEATER PANEL
LCC
LC
FOLLOW-UP MOTOR
M1
M2
M3
8-POLE SWITCH
SIGNALS FROM MASTER COMPASS
RELAY TRANSMITTER SUPPLY SWITCH ON RELAY TRANSMITTER REPEATER PANEL
2S3
2S2
2S1
1S3
1S2
1S1
36-1 AND 1-1 SYNCHRO CONTROL TRANSFORMERS
T1
T2
RELAY TRANSMITTER AMPLIFIER
8-POLE SWITCH

B. SCHEMATIC DIAGRAM

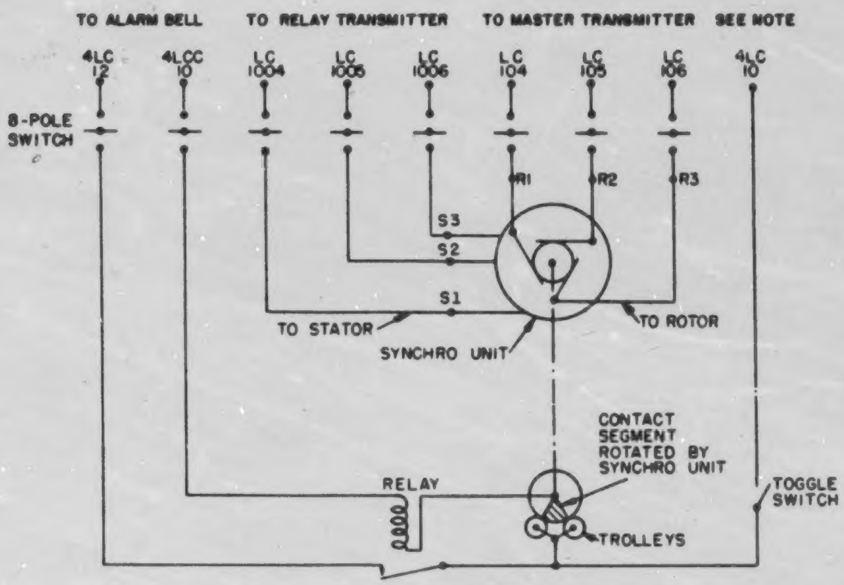
40.45

Figure 12-36.—Sperry Mk 11 Mod 6 relay transmitter.


TROLLEY
RECEIVER-DISK DIAL POINTER
TROLLEY SETTING SCALE
LOCK SCREW FOR TROLLEYS
RECEIVER-DISK DIAL
LEAD TO CENTER CONTACT
CONNECTION TO TROLLEYS
ZERO SETTING KNOB
SYNCHRO UNIT
RECEIVER DISK
TROLLEY
RECEIVER-DISK DIAL POINTER

CONTACT MECHANISM

A


TO ALARM BELL
TO RELAY TRANSMITTER
TO MASTER TRANSMITTER
SEE NOTE
4LC 12
4LCC 10
LC 1004
LC 1005
LC 1006
LC 104
LC 105
LC 106
4LC 10
8-POLE SWITCH
R1
R2
R3
S3
S2
S1
TO STATOR
TO ROTOR
SYNCHRO UNIT
CONTACT SEGMENT ROTATED BY SYNCHRO UNIT
RELAY
TOGGLE SWITCH
TROLLEYS

NOTE: SUPPLY LEADS 4LC10 AND 4LCC10 FED TO RELAY TRANSMITTER REPEATER PANEL.

SCHEMATIC DIAGRAM

B

40.47

Figure 12-37.—Sperry Mk 11 Mod 6 gyrocompass differential alarm relay.

ERROR CORRECTION

Unless located on a steady platform at the Equator, a gyrocompass will not point to true north, but will be slightly deflected toward the east or west, depending on conditions. It is possible to predict the amount or angle of deflection, when the latitude, ship's speed, and direction of the ship's motion are known. This angle is called the VIRTUAL MERIDIAN. The difference between the virtual meridian and the true meridian is the sum of two errors: the tangent-latitude error, and the speed-course-latitude error. Other errors caused by roll and pitch of the ship and acceleration are also present. But because these errors are small, and come and go, they are not corrected when the virtual meridian is being determined.

TANGENT LATITUDE ERROR

The tangent latitude error is the direct consequence of the method used in the Sperry compass to damp the horizontal oscillations of the gyro axle. At the equator the compass settles in the meridian with its axle horizontal and with equal amounts of mercury in each tank. In any other latitude a torque must be applied to the gyro to keep it continually precessing or the gyro will leave the meridian because of its rigidity of plane and the earth's rotation. For the compass to reach a settling point, the north axle must be tilted upward in northern latitudes and downward in southern latitudes.

The upward tilt of the axle in northern latitudes causes an excess amount of mercury to collect in the south tanks. As previously explained, the point of connection between the mercury ballistic and the rotor case is offset a short distance east of the vertical axis to provide damping. Therefore, the excess mercury in the south tanks exerts a force through the offset connection that applies a torque simultaneously about both the horizontal and vertical axes. The downward precession tending to tilt the north axle below the horizontal is offset by the earth's rotation tending to tilt the axle upward. This action prevents the torque produced by the mercury ballistic from bringing the axle horizontal and in the meridian. The north axle leads or lags the meridian just enough to keep the gyro precessing at a constant rate. The angle between the meridian and the settling position is called the TANGENT LATITUDE ERROR. This error is compensated for in the Sperry Mk 11 Mod 6 gyrocompass by an auxiliary latitude corrector (fig. 12-38) that enables the lubber's line to be moved manually the exact amount of the error and in the proper direction. The corrector is calibrated in degrees of north and south latitude. Setting the latitude dial to the local latitude moves the lubber's ring and the transmitter stator so that the compass card and the repeaters indicate the true angle between the ship's heading and geographical north.

SPEED-COURSE-LATITUDE ERROR

The magnitude of the speed-course-latitude error depends upon the speed, course, and latitude of the ship. The gyrocompass tends to be north-seeking because north is at right angles to the west-to-east direction in which the earth's rotation carries the compass. The gyrocompass thus tends to settle with its axle at right angles to its plane to travel through space at all times.

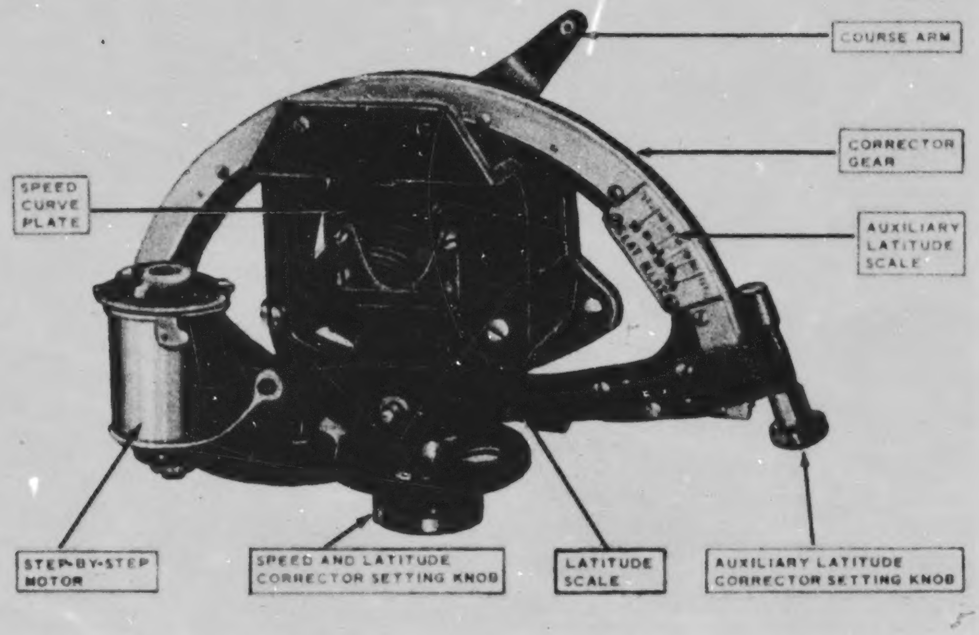
A compass on the earth's surface is carried from west to east only when it is stationary with respect to the earth's surface, or when it is moving true east or true west. If any component of the course is north or south, the plane of motion is no longer west to east.

If the ship travels on any other than a true east or true west course the ship's motion carries the compass in some direction other than west to east. In this case the compass seeks a new resting position away from the true meridian. This position is at right angles to the plane containing the path of the compass.

The speed-course-latitude error is westerly if any component of the ship's course is north. Conversely, the speed-course-lattitude error is easterly if any component of the ship's course is south. The magnitude of this error is proportional to the latitude, the speed, and the course of the ship. The direction of this error is determined by the ship's course.

Compensation for Errors

The Sperry compass is provided with a speed and latitude corrector to compensate for the speed, course, latitude error and an auxiliary latitude corrector that compensates for the tangent latitude error. The speed and latitude corrector consists of a stationary plate (fig. 12-38) on which are engraved several speed curves, and a movable plate on which are engraved various latitudes. The movable plate is controlled by means of an adjusting knob. The corrector is set by turning the adjusting knob until the mark



40.49

Figure 12-38.—Speed-course-latitude correction mechanism.

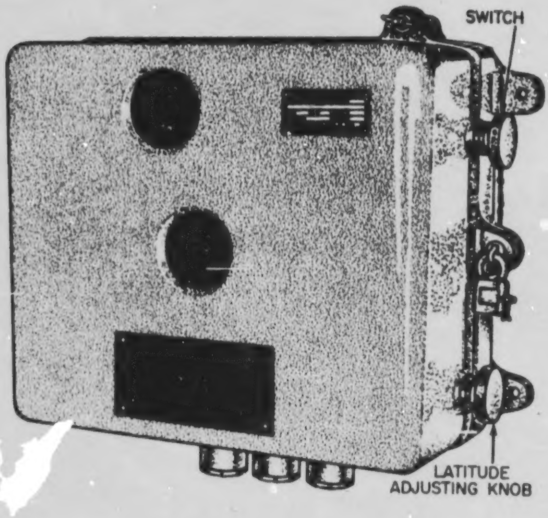
indicating the local latitude intersects the speed curve corresponding to the ship's speed. When set to the proper speed and latitude, the corrector automatically shifts the lubber's line in the right direction and the proper amount to compensate for ship's speed and earth rate at the local latitude.

Changes in ship speed may be automatically introduced into the corrector mechanism by an automatic speed corrector unit associated with the Sperry Mk 11 Mod 6 gyrocompass. A speed input from the ship's underwater log positions a step-by-step transmitter in the automatic speed corrector (fig. 12-39). The step-by-step transmitter drives the step-by-step motor (fig. 12-38) to position the corrector mechanism.

The effect of the ship's course on the speed, course, latitude error is automatically compensated for by an eccentric groove, or COSINE CAM cut into the upper surface of the large azimuth gear which is located below the small azimuth gear. As the ship turns around the compass, the cosine cam moves a follower, or course arm (fig. 12-34) forward or aft. The movement of the arm operates a system of levers that automatically shifts the lubber's line the proper amount and in the right direction to compensate for ship's course.

On a northerly course, the cam is in its most forward position and the maximum correction for speed and latitude is applied to the lubber's line.

When the speed and latitude corrector is set to the proper speed and latitude, and is combined with this automatic course compensating feature, the total resultant correction for the speed, course, latitude error is transmitted to the lubber's line. The lubber's line then moves automatically to port or starboard the exact amount of the resultant correction. The movement of the lubber's line ring shifts the stators of the synchro transmitters so that the repeaters and the compass cards indicate the true heading on all courses.



40.48
Figure 12-39.—Sperry automatic speed corrector.

BALLISTIC DEFLECTION ERROR

The ballistic deflection error is dependent upon the rate of change of the ship's speed or course. It is a transient error that is introduced into the compass only during changes of speed or course. The gyrocompass is subjected to the action of the forces of inertia when a ship changes speed or course.

When a ship steaming north increases its speed, the mercury in the mercury ballistic is forced aft, or to the south, by the effect of its inertia. A portion of the mercury in the north container flows to the south; the south container becomes heavier and a downward force of gravity is exerted on the south end of the rotor axle. A similar force acts on the pendulous weight compass and pushes south at the bottom of the rotor. This is equivalent to a downward force on the north end of the axle.

In either case, fortunately, the direction of the force is such as to cause the compass to precess toward a settling position which compensates for the new speed-course-latitude error. The force is exerted during the time in which the change is being made and its strength is proportional to the rate of the change. Thus, a rapid change in speed results in a comparatively large force being exerted for a short time, whereas a more gradual change of the same amount results in a smaller force being exerted for a longer time. The total precession in either case is the same. The precession resulting from such a force is called BALLISTIC DEFLECTION. When the ballistic deflection is exactly equal to the change in the speed, course, latitude error for a change in speed or course, the compass settles quickly in the virtual meridian and there is no error in its indication. When the ballistic deflection is not equal to the change in the speed, course, latitude error, the resulting error is called the BALLISTIC DEFLECTION ERROR. This error consists of a series of decreasing oscillations across the normal settling point of the compass. Therefore, it cannot be corrected by shifting the lubber's line or the compass card.

Sperry compasses that are used for navigation are constructed with a fixed undamped period of about 85 minutes at 40.7° latitude. Hence, there is no ballistic deflection error at 40.7° latitude with this period. In fact, the error at any latitude is small and does not affect the accuracy of navigation to any great extent.

Compasses that are used for fire control must maintain a constant and accurate indication of the ship's heading. This condition is accomplished by maintaining a period of about 85 minutes in all latitudes. On these compasses the mercury ballistic is constructed so that the tanks can be set closer to, or farther from, the horizontal axis about which they operate. At the equator, the tanks are set in their innermost position. For north and south latitudes where the period would normally be longer, the tanks are set farther out. This adjustment provides the additional torque necessary to cause a faster rate of precession and thereby shorten the period. To set the ballistic for any latitude, a knob (thumb wheel) mounted on the ballistic frame (fig. 12-27) is turned until an attached scale indicates the correct latitude.

AUTOMATIC CORRECTION DEVICES

The Sperry Mk 11 Mod 6 gyrocompass is provided with two automatic devices associated with error correction. They are (1) an automatic speed corrector associated with speed course, latitude error correction, and (2) an automatic damping eliminator which prevents the introduction of ballistic damping errors during rapid changes in ship's speed or course.

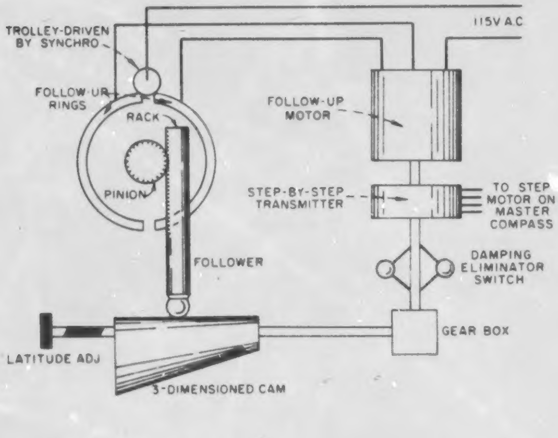
AUTOMATIC SPEED CORRECTOR

The Sperry automatic speed corrector (fig. 12-39) automatically transmits corrections for the ship's speed to the speed correction mechanism on the master compass. The step-by-step motor geared to the corrector spindle on the speed correction mechanism (fig. 12-38) is remotely controlled by a step-by-step transmitter in the automatic speed corrector. A switch is mounted on the compass for opening the motor circuit when setting the correction device by hand.

The automatic speed corrector is mounted on the bulkhead in the vicinity of the master compass.

The ship's speed is introduced into the automatic speed corrector by a synchro motor controlled by the underwater log. In operation, the rotor of the synchro motor takes a position representing the ship's speed and correspondingly locates a pair of trolleys bearings on a follow-up ring assembly (fig. 12-40).

When the position of the trolleys is not on the gap in the followup contact rings, the followup motor is energized. The motor drives a three-dimensioned cam, which, by means of a follower and gears, drives the followup contact rings into synchronism with the trolleys. The cam is designed so that when it is correctly positioned lengthwise for the local latitude, the amount it must turn to synchronize the trolleys and rings is proportional to the speed correction that must be set into the compass. This correction is transmitted to the step-by-step motor on the compass by a step-by-step transmitter driven by the followup motor that rotates the cam. The followup motor also drives a centrifugal type damping-eliminator switch to eliminate damping during rapid changes in speed.



40.50

Figure 12-40.—Schematic diagram of Sperry automatic speed corrector.

The instrument (fig. 12-39) is provided with a dial to indicate the ship's speed, graduated in knots, and visible through a window in the cover. The latitude adjustment, which determines the lengthwise position of the three-dimensioned cam, is shown on another dial, also visible through a window in the cover.

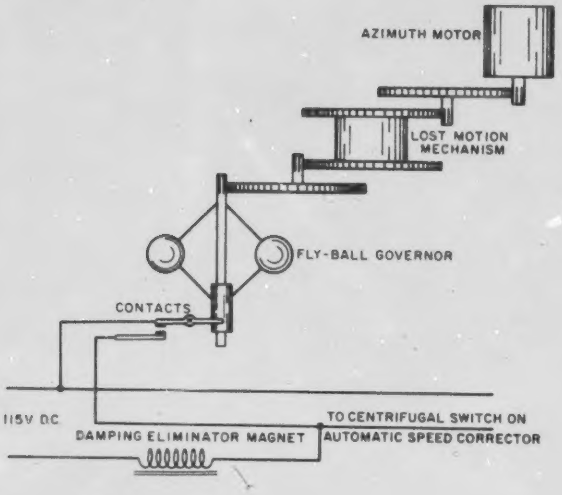
AUTOMATIC DAMPING ELIMINATOR

The Sperry compass uses a mercury ballistic connected slightly east of the true vertical axis of the gyro to damp the oscillations across the meridian, or about the vertical axis, as stated previously. The slight error introduced by this damping arrangement during changes in speed or course is called the BALLISTIC DAMPING ERROR. This error, like the ballistic deflection error, oscillates and is a temporary error.

The ballistic damping error is eliminated in the Sperry Mk 11 Mod 6 gyrocompass by means of an automatic damping eliminator. This device automatically moves the mercury ballistic connection arm from the offset position to the true vertical axis of the gyro whenever a change in the ship's course is greater than 15° and faster than 40° per minute, or whenever the ship's speed changes faster than 2 knots per minute. Moving this offset connection to the true vertical axis eliminates the torque about this axis caused by the centrifugal force and prevents the compass from going through a damped oscillation. A push-button is located on the bridge alarm indicator (fig. 12-33) for manual elimination of damping.

The automatic damping eliminator (fig. 12-41) consists of two centrifugal governor-operated switches, one geared to the azimuth motor, and one to the followup motor of the automatic speed corrector; and an electromagnet that moves the mercury ballistic connecting arm from its offset position to a true vertical position.

The governor switch geared to the azimuth motor takes care of changes in course where no change in speed is involved. The governor is driven through a gear train which speeds the governor shaft to about 4300 revolutions to one revolution of the phantom. To eliminate constant starting and stopping of the governor


AZIMUTH MOTOR
LOST MOTION MECHANISM
FLY-BALL GOVERNOR
CONTACTS
115V DC
TO CENTRIFUGAL SWITCH ON AUTOMATIC SPEED CORRECTOR
DAMPING ELIMINATOR MAGNET

40.51
Figure 12-41.—Schematic diagram of Sperry automatic damping eliminator.

when the ship is yawing, a lost-motion mechanism and a helical driving spring are inserted between the switch driving gear in the azimuth motor train and the first gear in the train to the governor shaft. As the ship yaws, the lost-motion mechanism comes into play. This mechanism prevents transmission of motion to the governor shaft.

If the ship turns more than 15 degrees, the helical spring is wound in one direction or the other until there is sufficient tension in the spring to set the governor in motion. As the governor spins, the balls fly up, raising a sliding collar on the governor shaft which engages an arm operating the magnet circuit contact, thus closing the 115-volt d-c supply circuit to the damping eliminator magnet.

A friction brake on the governor, and a spring disk friction clutch in the gear train, prevent the governor from spinning too fast. The contacts are adjusted so that the circuit is closed when the ship turns at a rate of more than 40 degrees per minute.

The gearing arrangement from the azimuth motor through the lost motion device to the fly-ball governor is also shown in figure 12-34.

The damping-eliminator switch (fig. 12-40) driven by the followup motor in the automatic speed corrector operates in a similar manner to eliminate damping during rapid changes in ship's speed.

OPERATION

Operating the compass consists of starting, stopping, adjusting correction devices, and making checks for any indications of abnormal operating conditions.

STARTING THE COMPASS

If possible the compass should be started at least four hours before it is needed. Before checking the compass make sure that all switches on the compass and repeater switchboards are off. Ensure that the gyro case lock and vertical ring lock (fig. 12-25) are in the locked position, and that the vacuum gage (not shown) indicates approximately 28 inches. Take hold of both sides of the phantom and vertical rings and turn slowly until the compass card indicates the approximate heading of the ship. Never turn the compass by exerting pressure on the compensating weights or mercury ballistic. Check the oil sight glass to ensure that the rotor bearings will be supplied with oil. Set the auxiliary latitude corrector, the speed and latitude corrector, and the ballistic latitude adjustment to the proper settings (discussed later). After completing the above checks, preceed to start the compass as follows:

1. After closing the necessary supply switches on the IC switchboard, turn the motor-generator transfer switch on the control panel (fig. 12-32) to the motor-generator set desired.
2. Press the starting pushbutton, turn the compass rotor switch to the motor-generator set in use, then close the d-c service switch.
3. When the gyro rotor has been running for about 30 minutes, close the followup supply switch, then wait approximately 15 minutes for the gyro rotor to come up to normal speed. Normal speed will be indicated by a reading of approximately 60 volts of the compass rotor supply voltmeter (fig. 12-32), and from 2 to 3 amperes on the compass rotor supply ammeter when the voltammeter selector switch is in the number 1 phase position.
4. Release the vertical ring lock, then release the gyro case lock. Be sure to release the vertical ring lock first.
5. Turn the azimuth motor supply switch on the control panel to ON, and note whether the

azimuth motor starts operating. It may be necessary to press the azimuth motor cutout detent release (fig. 12-32) to complete the circuit to the azimuth motor.

6. Turn the battery generator transfer switch on the battery throwover panel to the motor-generator set in use, close the battery switch, and adjust the battery charging rate with the voltage adjusting rheostat.

7. Level the rotor case, then precess the compass to the approximate heading of the ship. To level the rotor case, apply a slight pressure on one side of a rotor case bearing housing as if to turn the compass in azimuth. If the rotor case starts to tilt in the wrong direction, apply the pressure to the other side of the housing. To precess the compass in azimuth, apply a slight downward pressure from the top of the rotor case bearing housing. If the compass starts to precess in the wrong direction, apply the pressure upward from the bottom of the housing.

8. Close the repeater supply switch on the IC switchboard (not shown), the 24-volt alarm switch on the battery throwover panel, (fig. 12-32), and the rotary switches for the relay transmitter supply and differential alarm relay on the relay transmitter repeater panel, (not shown).

9. Close the switch on the relay transmitter (fig. 12-36A).

10. Close the followup switch on the relay transmitter amplifier panel (fig. 12-32), wait about one minute for the tube filaments to heat up, then close the azimuth motor switch. The relay transmitter should synchronize immediately to the same heading as the master compass.

11. Close the toggle switch on the differential alarm relay (fig. 12-37B), and turn on all repeaters.

SETTING CORRECTION DEVICES

The gyrocompass operator must ensure that all error correction devices are properly set before starting the compass. While the ship is underway; he is further concerned with adjusting these devices. For the Sperry Mk 11 Mod 6 gyrocompass system, these devices include the speed and latitude corrector, the automatic speed corrector, the auxiliary latitude corrector, and the ballistic latitude adjustment.

Speed and Latitude Corrector

To set the speed and latitude corrector (fig. 12-38), without utilizing the automatic speed corrector, turn the knurled knob at the upper center of the corrector until the point on the latitude scale corresponding to the local latitude intersects the speed curve corresponding to the ship's speed. For maximum accuracy the corrector should be kept within 2 degrees of the local latitude and within 2 knots of the ship's speed. It is impractical, however, to attempt to keep the speed settings within these limits witout utilizing the automatic speed corrector.

To put the automatic speed corrector in operation, set the speed and latitude corrector at zero, and turn the corrector step-by-step motor switch to ON. After the ship is underway and the underwater log is in operation, turn the switch on the upper right side of the automatic speed corrector to ON. Set the corrector to the local latitude with the latitude adjusting knob. Adjust the latitude setting when the ship's latitude changes as much as two degrees or as ordered by the ship's navigator.

Auxiliary Latitude Corrector

To set the auxiliary latitude corrector, turn the smaller knurled knob on the right side of the corrector (fig. 12-38) until the line engraved on the large gear segment coincides with the point on the latitude scale corresponding to the local latitude. Change this adjustment for changes in ship's latitude of 2 degrees, or as ordered by the ship's navigator.

Ballistic Latitude Adjustment

To make the ballistic latitude adjustment, turn the knurled latitude setting thumbwheel (fig. 12-27) until the pointer on the ballistic frame points to the local latitude on the latitude scale located on top of the mercury reservoir. Make the same adjustment on the opposite side of the ballistic. Make these adjustments for changes in latitude of 10 degrees, or as ordered by the ship's navigator.

STOPPING THE COMPASS

To stop the Sperry Mk 11 Mod 6 gyrocompass, proceed as follows:

1. Turn the switch on the automatic speed corrector, and the step-by-step speed corrector motor switch on the master compass to OFF.

2. On the battery throwover panel (fig. 12-32) open the 24-volt alarm switch, the battery switch, and the battery generator transfer switch.

3. Open the toggel switch on the differential alarm unit, then open the azimuth motor switch and the followup switch on the relay transmitter amplifier panel.

4. Open all repeater switches, and the rotary switch for the differential alarm unit.

5. Open the azimuth motor supply switch on the control panel, then lock the gyro case, and vertical ring locks (fig. 12-25). Be sure to lock the gyro case lock first.

6. On the control panel (fig. 12-32), open the followup supply switch, the d-c service switch, the compass rotor switch, and the motor generator transfer switch.

7. Open the repeater supply, and control panel supply switches on the IC switchboard, (not shown).

INDICATIONS OF NORMAL OPERATIONS

Normal operating conditions for the compass system are indicated by the various electrical meters and overload indicators on the gyrocompass switchboard. Normal readings for the electrical meters are listed in the manufacturer's technical manual.

As these readings may vary slightly for different installations, the average meter readings during actual normal operation should be recorded and used as the normal readings.

Normal operating conditions are also indicated by the gyro case level and vacuum gauge on the sensitive element, and the presence of the blue flame in the compass followup and relay transmitter power amplifier thyratrons.

Study the gyrocompass installation on your ship and become familiar with all indications of normal operation. This will enable you to recognize and abnormal condition immediately.

HIGH LATITUDE MODIFICATION

The Sperry Mk 11 Mod 6 compass described in this chapter has been modified to permit more accurate operation above 60 degrees latitude. Parts of the compass which have been changed are the mercury ballistic, the auxiliary latitude corrector, the speed and latitude correction, and the automatic speed corrector.

The modified mercury ballistic has larger pots and an enlarged frame. The mounting of the pots permits them to be swung through an arc of 136 degrees instead of 110 degrees of the former unit. A valve between one pair of pots permits these to be disabled when the ship is operating below 60° latitude. There are two latitude scales for each set of pots; a green scale for latitudes 0 to 60 degrees, and a red scale for 60 to 80 degrees. The south-west and the north-east pots have green scales; the north-west and south-east pots have the high-latitude red scales.

A knurled nut moves the pots through a worm and sector gear. When the ship is at the Equator, the pots are turned in close to the case. As latitude increases, you must turn the nut to move the pots out, until they are fully extended at a latitude of 60°. If the ship continues to higher latitudes the second pair of pots is activated, all pots are swung in, and adjusted outward again as latitude increases to 80°.

The new scale on the auxiliary latitude corrector is calibrated from 0 to 60 degrees in green, and from 60 to 80 degrees in red. The new scale makes it easy to adjust the lubber's line at the higher latitudes. The speed and latitude corrector also has a modified scale to facilitate its adjustment. A red engraving on this scale is for use above 70 degrees of latitude.

You must take care in adjusting this compass when you move to and from the higher latitudes. The correction devices must be properly set, and operators must note which scale is in use. Before closing the valve to disable the auxiliary pots when returning to lower latitude operation, be sure the compass is level, so the pots will contain an equal amount of mercury.

CHAPTER 13

GYROCOMPASSES, PART II

The Navy's need for a compact, rugged, low-voltage gyrocompass led to the development of the Mk 23 gyrocompass by the Naval Ship Systems Command in conjunction with the Sperry Piedmont Company. This "latest development" gyrocompass applies the gyroscopic principles discussed in the preceding chapter, and incorporates some major changes in gyrocompass design, such as the electronic control system and a sensitive element suspended in oil. This chapter concerns the Sperry Mk 23 Mod 0, which serves as a representative gyrocompass, and explains how its many components and systems function and how it can be operated.

SPERRY MK 23 MOD 0 GYROCOMPASS

By design, the Sperry Mk 23 Mod 0 gyrocompass is small and capable of withstanding the severe operating conditions encountered in amphibious craft and submarines without sacrificing its primary function of furnishing accurate heading data. It is also used as an auxiliary gyrocompass aboard larger combatant ships. The force of gravity, instead of acting directly to control the compass, merely acts on a special type of electrolytic bubble level (gravity reference) which generates a signal proportional to the tilt of the gyro axle. This signal, after amplification, is used to apply torque electromagnetically about the vertical and/or horizontal axes to give the compass the desired period and damping. The gyro unit is enclosed in a sphere called a gyrosphere, and is suspended in oil.

The compass is compensated for speed error, latitude error, unbalance, and supply voltage fluctuations. In addition to the normal operating range of latitudes, the compass incorporates controls which make it suitable for accurate operation in high latitudes, and as a directional gyro near the poles.

An electronic followup system is provided which furnishes accurate transmission of 1- and 36-speed heading data.

The system consists of the master unit, control cabinet, speed units, alarm control, and the alarm bell, and compass failure annunciator as shown in figure 13-1.

MASTER UNIT

The master unit (fig. 13-1) consists of a shock mounted oil filled binnacle and the gyrocompass element. The unit is designed for deck mounting and the compass element is gimbaled in the binnacle so as to have a freedom of ±45 degrees about the roll and pitch axes. The sensitive element has a freedom of ±70 degrees about its horizontal axis. Heaters in the binnacle keep the oil bath at a temperature of 100° F, and drain plugs are provided in the lower bowl for draining the oil. The complete master unit weighs approximately 100 pounds.

Gyrocompass Element

The gyrocompass element is the principle unit of the compass system and consists of three basic elements: the sensitive element, phantom element, and the spider element.

THE SENSITIVE ELEMENT.—The sensitive element (fig. 13-2) consists of the vertical ring, adapter ring, and gyrosphere.

The gyrosphere is pivoted about the vertical axis within the vertical ring. The vertical ring, in turn, is pivoted about the horizontal axis in the adapter ring. At right angles to the vertical ring is a horizontal ring, carrying the pivots about which the vertical ring and gyrosphere rotate. The horizontal ring also provides surfaces for mounting the electrolytic level (gravity reference), followup pickoff, and leveling torquer.

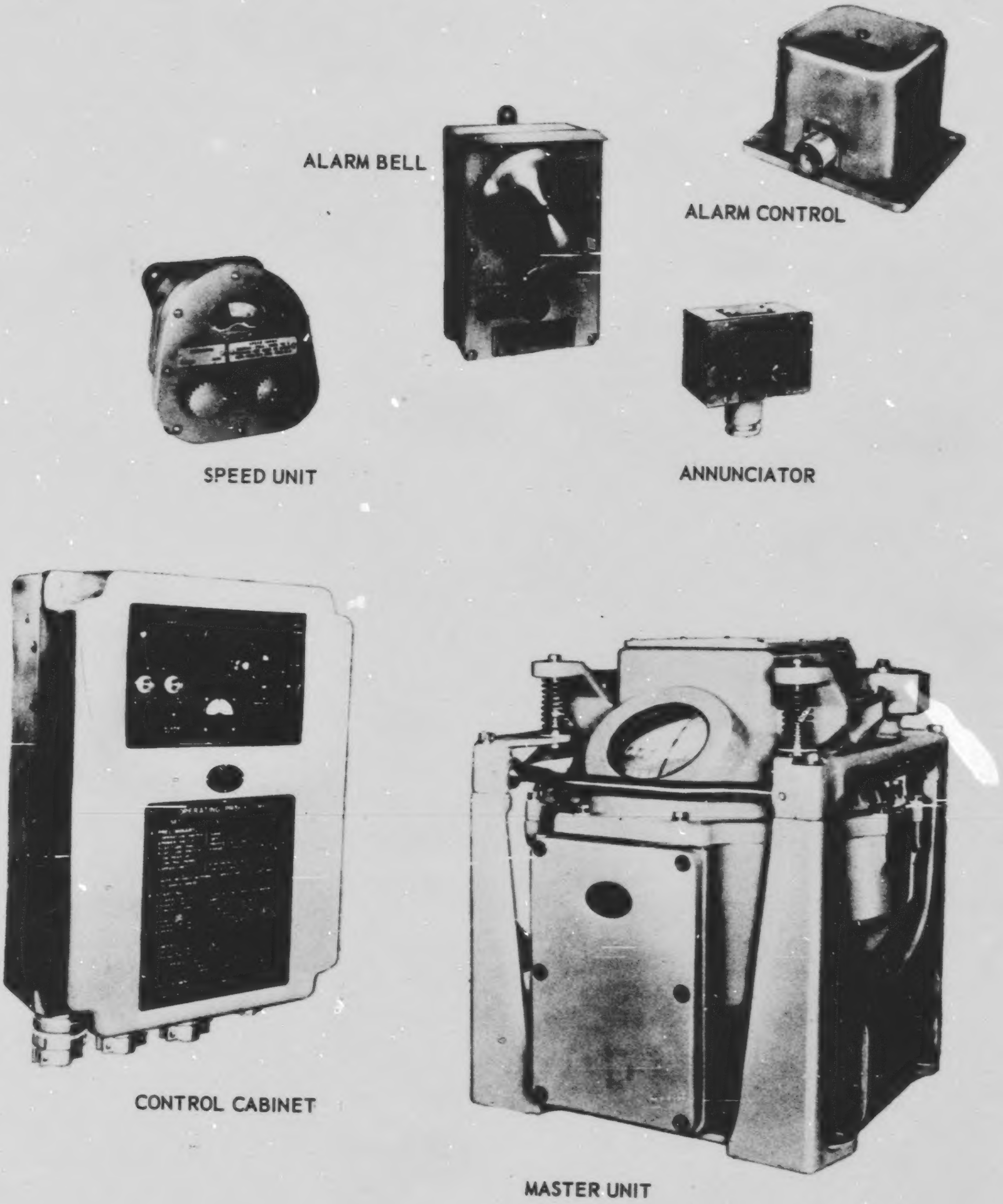
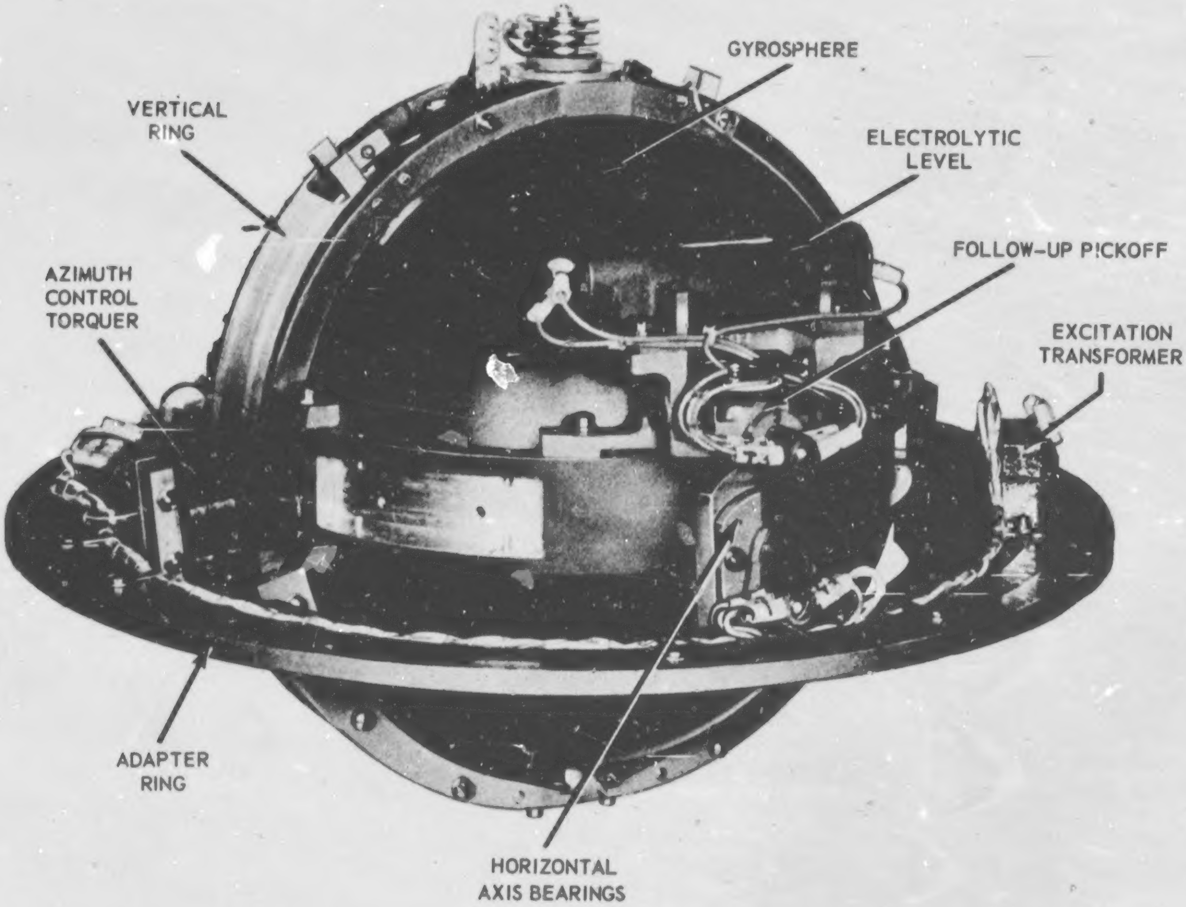

ALARM BELL
ALARM CONTROL
SPEED UNIT
ANNUNCIATOR
CONTROL CABINET
MASTER UNIT
7.167

Figure 13-1. — Mark 23 Mod 0 gyrocompass equipment.



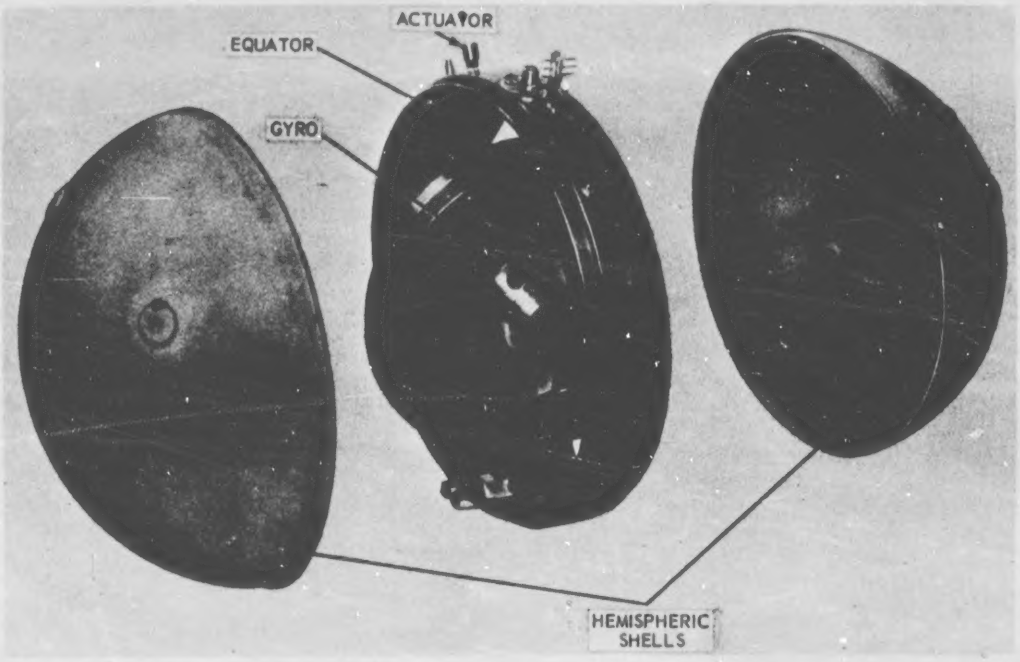
7.175

Figure 13-2.—Sensitive element.

The adapter ring provides mounting surfaces for the azimuth control torquers, the horizontal axis bearings, and the excitation transformer. In addition, the adapter ring provides a method of mounting the sensitive element to the phantom bowl, which provides for ready replacement of the sensitive element if the need should arise.

The gyroshpere is the heart of the whole system, as it encloses the gyro and is the north-seeking part of the compass. It is composed of a center ring called the equator and two hemispherical shells (fig. 13-3). The gyro unit is driven by a 2-pole, 115-volt, 400-cycle, 3-phase squirrel cage induction motor. The rotor speed is approximately 23,600 rpm and the direction is clockwise when viewed from the south end. The gyro is hermetically sealed within the sphere and the complete unit is suspended in oil. The gyrosphere is evacuated and partially filled with helium gas, which serves to transfer the heat generated by the gyro motor windings to the surface of the sphere.

When the weight and buoyancy of the gyro are properly adjusted in the oil, no load is placed on the vertical pivots, the vertical bearings serving only as guides for the sphere. This liquid suspension eliminates the effect of shifts of the center of mass of the sensitive element with respect to the suspension axis. Liquid suspension also serves to protect the gyro from destructive shocks which are absorbed by the oil-filled compass enclosure,



7.173

Figure 13-3. — Exploded view of gyrosphere.

and the acceleration effects on the sensitive element are minimized because the center of gravity and center of buoyancy coincide. In addition to eliminating the load on the vertical pivots, oil flotation greatly reduces the load on the horizontal axis pivots. Only the weight of the vertical ring and its components, which are also reduced in weight due to partial flotation, loads the horizontal bearings.

PHANTOM ELEMENT. — The phantom element (fig. 13-4), is a bowl-shaped casting supported on ball bearings, located within the spider, and rotates about the vertical axis of the gyrosphere. As the ship turns with respect to the gyrosphere, the phantom is servomotor driven by the followup system so as to always maintain the horizontal axis of the vertical ring at right angles to the gyro axle (fig. 13-5). The phantom element mounts the azimuth gear and slip rings.

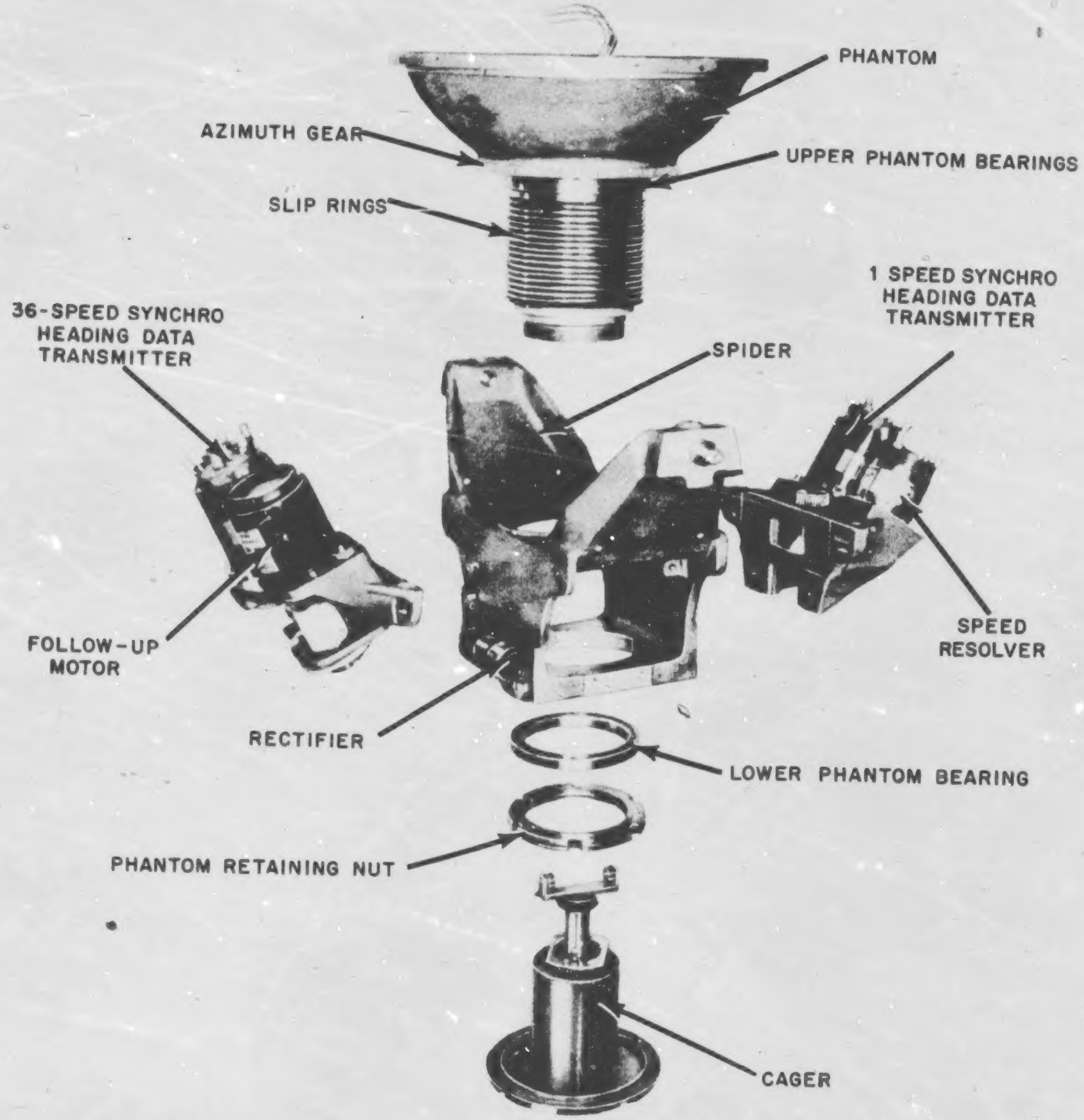
SPIDER ELEMENT. — The spider element (figs. 13-4 and 13-5) is a cast member having two ribbed arms carrying pivots which fit in bearings on the gimbal ring. The lower section carries the bearings supporting the phantom and caging mechanism. The cager is solenoid operated, and fits up into the hollow shaft of the phantom. Mounted on the spider are the 1- and 36-speed synchro heading data transmitters, the followup motor, and the speed resolver. The spider supports the phantom, gyrosphere, and vertical ring assembly. The spider, in turn, is supported by the gimbal ring and the complete gyrocompass element (fig. 13-6) is gimbaled in the binnacle by a gimbaling system.

CONTROL CABINET

The control cabinet (fig. 13-1) contains all the equipment required for operating and indicating the condition of the master compass except the compass failure annunicator and alarm bell. It houses the control panel, control amplifier, followup amplifier, and power supply.

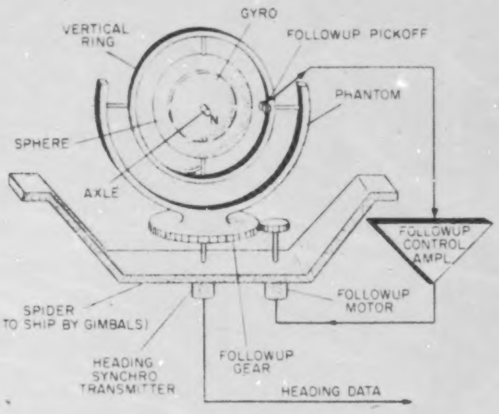
SPEED UNIT

The speed unit (fig. 13-1) contains the necessary components to produce an electrical


PHANTOM
AZIMUTH GEAR
UPPER PHANTOM BEARINGS
SLIP RINGS
1 SPEED SYNCHRO HEADING DATA TRANSMITTER
36-SPEED SYNCHRO HEADING DATA TRANSMITTER
SPIDER
FOLLOW-UP MOTOR
SPEED RESOLVER
RECTIFIER
LOWER PHANTOM BEARING
PHANTOM RETAINING NUT
CAGER

27.159

Figure 13-4.—Exploded view of phantom, spider, and cager.



7.174

Figure 13-5. — Followup controls.

signal proportional to the ship's speed, as will be discussed later. Speed data is received from the ship's underwater log equipment, or set in manually. Speed range of the unit is 0 to 40 knots.

ALARM CONTROL

The alarm control (fig. 13-1) contains the necessary relays and components to actuate a flashing light or bell alarm when certain portions of the system become inoperative.

ALARM BELL AND ANNUNCIATOR

The alarm bell (fig. 13-1) is a standard Navy B-10 bell. A Navy type B-51 or B-52 alarm panel may be used in place of the annunciator. The alarms are actuated by the alarm control and either the bell or annunciator, or both, may be used to indicate system failure.

MK 23 GYROCOMPASS CONTROLS

All controls for the Mk 23 gyrocompass system (fig. 13-7) may be divided into two systems, the compass control system and the followup system. The compass control system may be further divided into three separate systems: the gravity reference system, the azimuth control system, and the leveling control system.

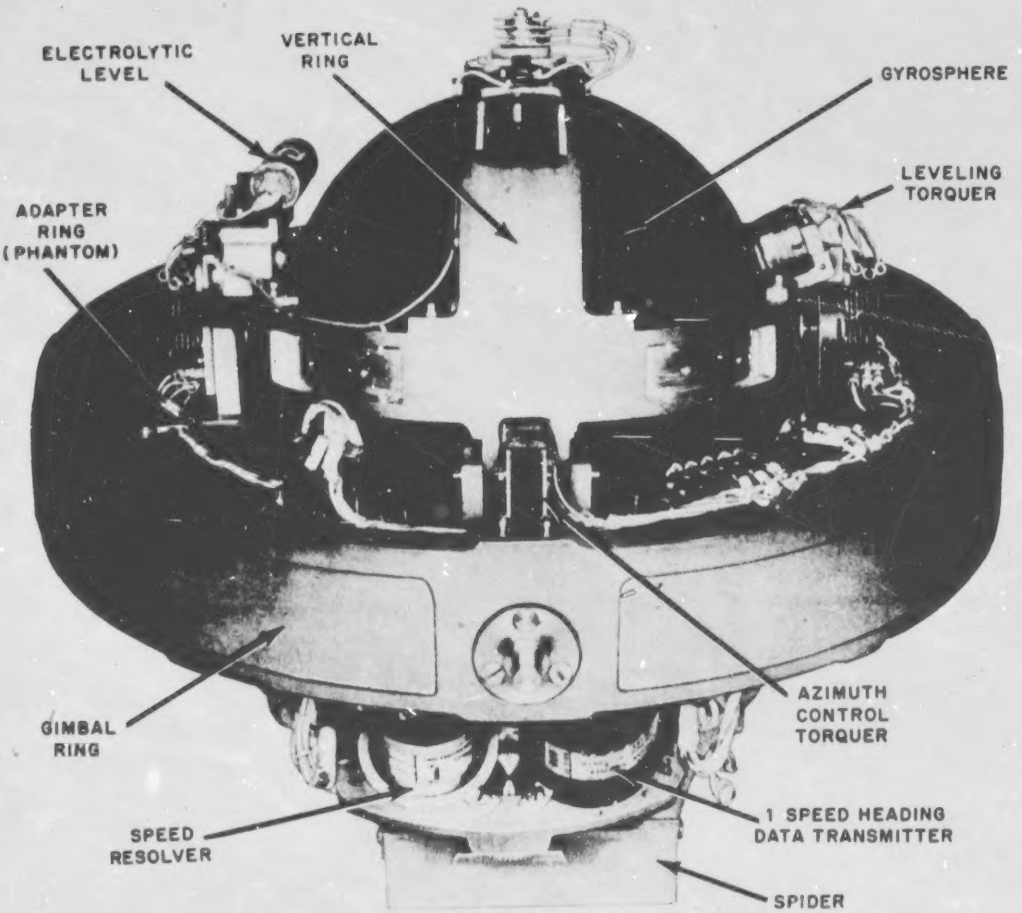
GRAVITY REFERENCE SYSTEM

The gravity reference system consists of the electrolytic bubble level, excitation transformer, and tilt signal amplifier.

The electrolytic bubble level (fig. 13-2) is mounted on the horizontal pivots, so that it is parallel to the gyro axle. It is a cylindrical glass vial containing three platinum electrodes, the vial being nearly filled with an electrolyte so that a bubble is formed at the top of the vial (fig. 13-8). When the vial is horizontal, the bubble is centered, and the resistance between the top electrode and either lower electrode is equal. If the vial tilts so that the bubble moves to the left, there is less electrolyte between the top electrode and the lower left electrode and consequently the resistance between the two is increased. The resistance between the top and lower right electrode is correspondingly decreased, the difference in resistance being proportional to the movement of the bubble.

The two lower electrodes are excited from the opposite ends of the output winding of the excitation transformer T102 mounted on the adapter ring. One phase of the 400-cycle, 115-volt, 3-phase power supply excites the excitation transformer primary winding. The tilt signal output from the electrolytic bubble level is obtained between an accurately determined center-tap (signal common) of the excitation transformer secondary and the top electrode. When the level is horizontal, the voltage between the top electrode and either lower electrode are equal and opposite and the tilt signal output is zero. When the level is tilted from the horizontal, an output signal voltage will be produced which is proportional in magnitude to the amount of tilt and with the phase or instantaneous polarity of the voltage dependent upon the direction of tilt.

The tilt signal amplifier is included in the control panel portion of the control cabinet, and is used to amplify the tilt signal before it is supplied to the leveling and azimuth control systems. The amplifier consists of a pentode stage (V301 fig. 13-8) and two cathode followers (V302A & B) one for the damping signal and the other for the meridian control signal. In addition to its normal 90-minute compass period with 65 percent damping, the compass includes a 30-minute settling period with 90 percent damping, which greatly reduces the time required for the compass to settle on the meridian after starting. The operation switch

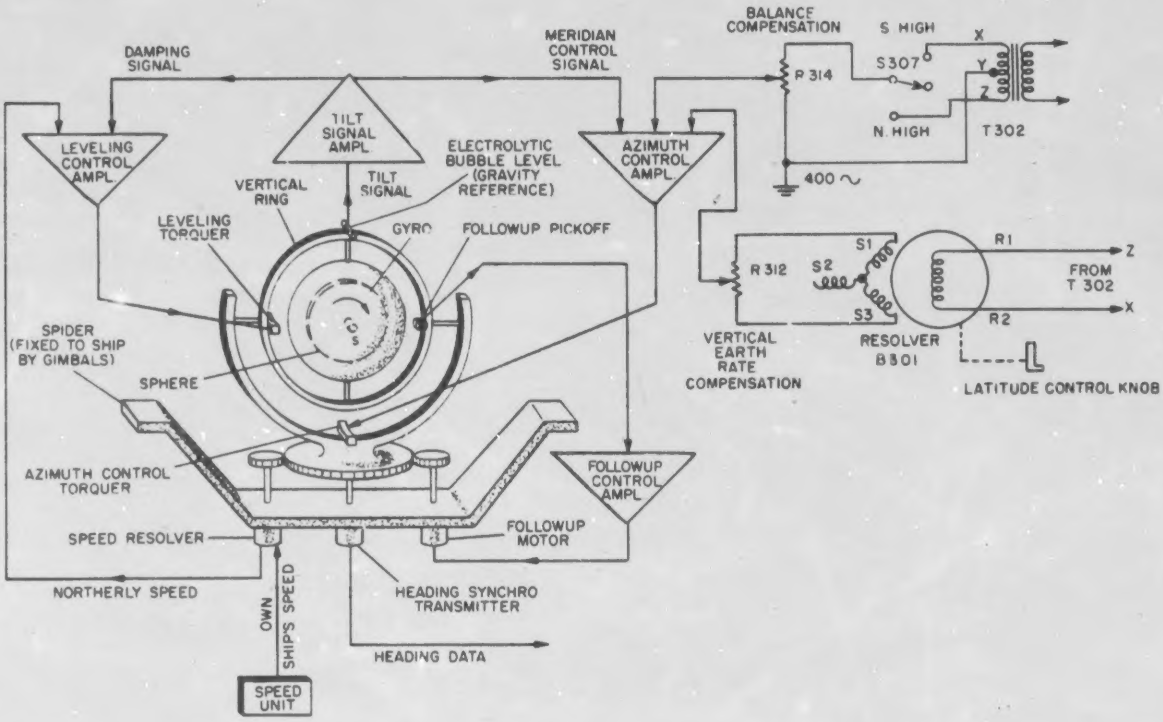

ELECTROLYTIC LEVEL
VERTICAL RING
GYROSPHERE
LEVELING TORQUER
ADAPTER RING (PHANTOM)
GIMBAL RING
AZIMUTH CONTROL TORQUER
1 SPEED HEADING DATA TRANSMITTER
SPEED RESOLVER
SPIDER

27.160

Figure 13-6.—Gyrocompass element.

S302, in conjunction with the tilt signal amplifier, alters the amplification of the tilt signal to obtain these two operating conditions.

The tilt signal is fed to the grid of V301 through the series grid resistor R301, and blocking capacitor C301. Cathode bias for V301 is obtained from a voltage divider, R303 and R304 connected across the plate supply. The output of V301 is fed to the grid of the meridian control signal cathode follower V302B. Potentiometer R310 in the cathode circuit of V302B provides a method of adjusting the magnitude of the meridian control signal. This adjustment is set at the factory and should not be changed. A portion of the output of V302B is fed back from the cathode through blocking capacitor C302 to the common connection between the plate load resistors R305 and R306 of V301. This feedback is of the same phase as the plate signal of V301 and therefore changes the potential at the common connection of R305 and R306 at the same time and in the same direction as the tilt signal input changes the potential at the plate end of R306. Thus, the voltage drop across R306 is maintained constant. This feature ensures that the V302B grid will remain negative with respect to the cathode and will not draw current. The change in voltage at the plate end of R306 is also reduced by negative feedback to the screen grid through voltage divider R307 and



BALANCE COMPENSATION
S HIGH
X
DAMPING SIGNAL
MERIDIAN CONTROL SIGNAL
R 314
S307
Y
Z
N. HIGH
T302
400 ~
LEVELING CONTROL AMPL.
TILT SIGNAL AMPL.
ELECTROLYTIC BUBBLE LEVEL (GRAVITY REFERENCE)
AZIMUTH CONTROL AMPL.
VERTICAL RING
TILT SIGNAL
LEVELING TORQUER
GYRO
FOLLOWUP PICKOFF
S1
R1
R 312
S2
Z
FROM T 302
S3
X
R2
SPIDER (FIXED TO SHIP BY GIMBALS)
VERTICAL EARTH RATE COMPENSATION
RESOLVER B301
LATITUDE CONTROL KNOB
SPHERE
AZIMUTH CONTROL TORQUER
FOLLOWUP CONTROL AMPL.
SPEED RESOLVER
FOLLOWUP MOTOR
NORTHERLY SPEED
OWN SHIP'S SPEED
HEADING SYNCHRO TRANSMITTER
HEADING DATA
SPEED UNIT

7.170

Figure 13-7. —Simplified diagram of Mk 23 gyrocompass with all controls.

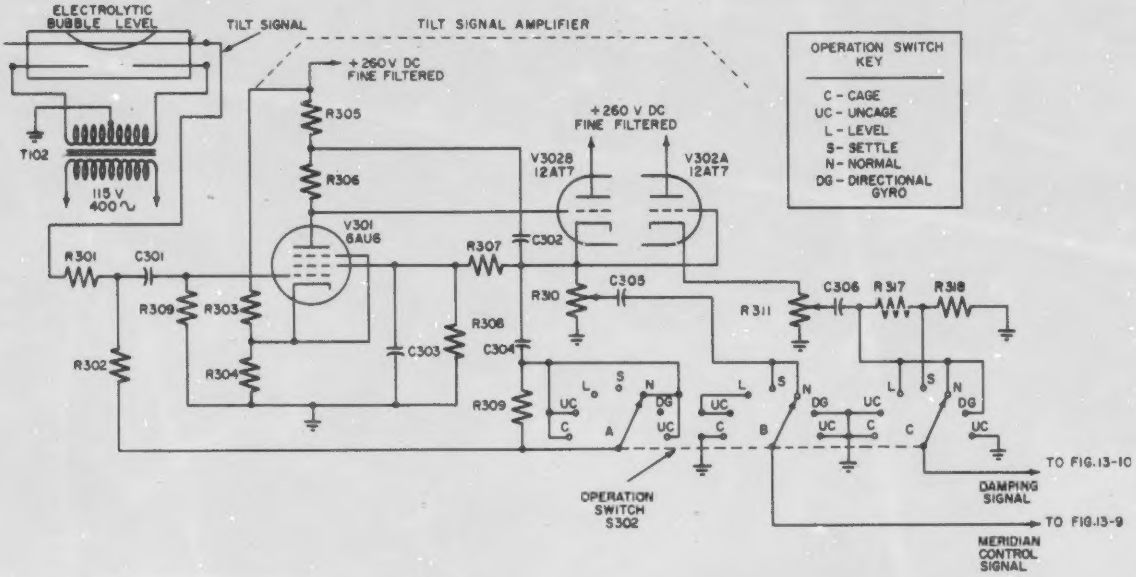
R308 to ground. The gain of the tilt signal amplifier without negative feedback is about 2000. The gain required for the 30-minute setting period is 90 and a gain of 10 is needed for the normal 90-minute period. To obtain the required gain for both periods, another feedback loop is provided from the V302B cathode through C304, R309, R302, and C301 to the V301 grid. For the 30-minute period (operation switch S302 (A) in the SETTLE position) both resistors R309 and R302 are in the feedback loop and the amplifier gain is 90. For the 90-minute period (operation switch S302(A) in the NORMAL position) resistor R309 is shorted out and the amplifier gain is 10.

The meridian control signal is obtained from the cathode of V302B and is fed through R310, C305 and operation switch S302(B), which connects the meridian control signal to the azimuth control amplifier during the normal and settle modes of operation.

The meridian control signal obtained from the V302B cathode is applied to the V302A grid. Potentiometer R311 in the cathode circuit, provides a factory adjustment of the damping signal. The damping signal is coupled through C306 to the voltage divider R317 and R318. The operation switch S302(C) connects the proper damping signal network for the mode of operation selected. During the settle mode of operation the signal is taken from the voltage divider giving the compass 90 percent damping. During level, normal, and directional gyro modes of operation the signal is taken via C306 from potentiometer R311. As the gain of the amplifier is increased during level, settle, and directional gyro, the signal voltage at R311 will be greater during these modes of operation. The meridian control signal, however, is disconnected by operation switch S302 (B) during certain modes of operation as discussed later.

AZIMUTH CONTROL SYSTEM

The azimuth control system (fig. 13-9) consists of the latitude switch S308, balance sense switch S307, latitude resolver B301, azimuth control amplifier, and azimuth control torquers.


ELECTROLYTIC BUBBLE LEVEL
TILT SIGNAL
TILT SIGNAL AMPLIFIER
+260V DC FINE FILTERED
+260 V DC FINE FILTERED
OPERATION SWITCH KEY
C - CAGE
UC - UNCAGE
L - LEVEL
S - SETTLE
N - NORMAL
DG - DIRECTIONAL GYRO
T102
115 V 400∿
R305
R306
V302B 12AT7
V302A 12AT7
V301 6AU6
R301
C301
R307
C302
R309
R303
R310
C305
C306
R317
R318
R311
R308
C304
C303
R302
R304
R309
UC
C
L
S
N
DG
A
B
C
OPERATION SWITCH S302
TO FIG.13-10
DAMPING SIGNAL
TO FIG.13-9
MERIDIAN CONTROL SIGNAL

27.162

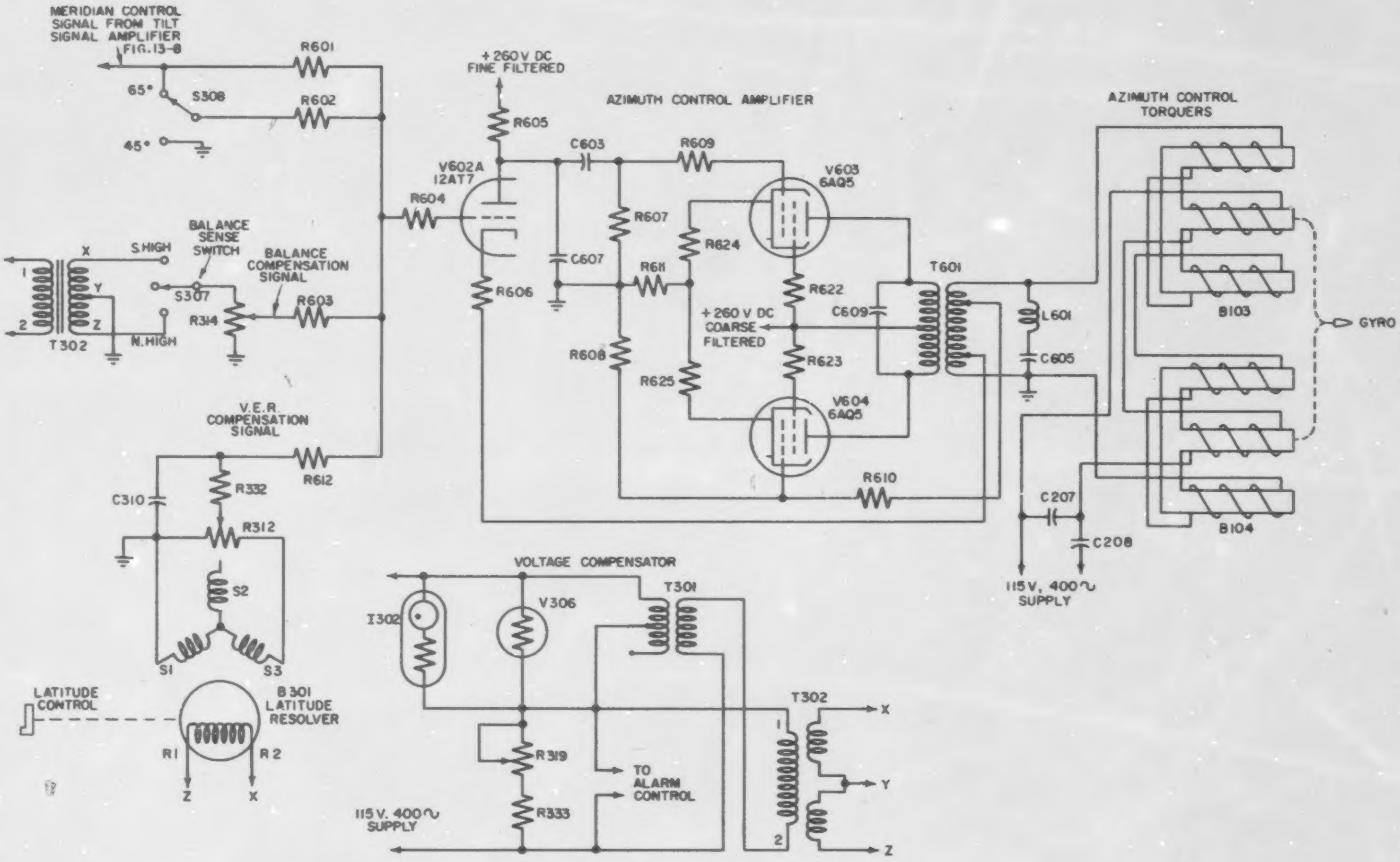
Figure 13-8.—Simplified schematic diagram of gravity reference system.

The system functions to produce a torque about the gyro horizontal axis, causing precession about the vertical axis toward the meridian, thus making the compass north seeking.

To give the compass the same period both at high and low latitudes, a latitude switch (S308), is provided which alters the connection of the meridian control signal mixing resistors R601 and R602. Above 75 degrees latitude the period of the Mk 23 compass lengthens considerably and the accuracy is thereby impaired. The directional gyro mode of operation is for use when in these latitudes. In this mode of operation the meridian control signal is disconnected from the azimuth control amplifier (by operation switch S302B fig. 13-8) and the gyro operates as a free gyroscope corrected for vertical earth rate and speed.

The balance adjustment (fig. 13-9) is provided as a convenience for shipboard operation. This adjustment permits the effects of mechanical unbalance in the master compass to be corrected without actually making the mechanical adjustments. The balance adjustment provides an electrical signal to the azimuth control amplifier to compensate for any mechanical unbalance. Power is supplied for the adjustment from the center tapped secondary of T302 in the voltage compensator. Balance sense switch S307 enables the operator to compensate for a north end high or south end high of the gyro axle. Potentiometer R314 is used to adjust the magnitude of the balance correction.

The effect of vertical earth rate causes the gyro to move in azimuth with respect to the earth as explained in the preceding chapter. To compensate for this effect, a vertical earth rate compensation circuit is provided consisting of a latitude resolver B301, potentiometer R312, resistor R332, and capacitor C310 (fig. 13-9). Vertical earth rate effect is the product of earth rate and the sine of the latitude. It is maximum at the poles (equal to earth rate itself) and zero at the equator. The input to the system is latitude which is set in manually by the latitude control knob on the control panel. The rotor of the resolver B301, is excited from the secondary of T302. This voltage is used as the earth rate reference voltage. The output voltage of the resolver (between S1 and S3) is the product of the excitation voltage (earth rate voltage) and the sine of the angle of the latitude control shaft displacement. This voltage is proportional to the local vertical


MERIDIAN CONTROL SIGNAL FROM TILT SIGNAL AMPLIFIER FIG.13-8
R601
R602
65°
S308
45°
+260 V DC FINE FILTERED
R605
AZIMUTH CONTROL AMPLIFIER
C603
R609
V603 6AQ5
V602A 12AT7
R604
R607
R624
C607
R611
R606
R622
+260 V DC COARSE FILTERED
C609
R608
R625
R623
V604 6AQ5
R610
T601
L601
C605
AZIMUTH CONTROL TORQUERS
B103
B104
GYRO
C207
C208
115V, 400∿ SUPPLY
BALANCE SENSE SWITCH
BALANCE COMPENSATION SIGNAL
S.HIGH
N.HIGH
S307
R314
R603
T302
X
Y
Z
1
2
V.E.R. COMPENSATION SIGNAL
R612
R332
C310
R312
S2
S1
S3
LATITUDE CONTROL
B301 LATITUDE RESOLVER
R1
R2
VOLTAGE COMPENSATOR
I302
V306
T301
R319
R333
TO ALARM CONTROL
115V. 400∿ SUPPLY

27.164

Figure 13-9.—Simplified schematic diagram of azimuth control system and voltage compensator.

earth rate. Potentiometer R312 across the resolver output is used to adjust and calibrate the vertical earth rate signal. Resistor R332 and capacitor C310 compensate for the phase shift in the resolver.

The voltage compensator shown in figure 13-9, although not considered a part of the azimuth control system, is essential to the proper functioning of the system. If the voltage on the torquer fields should vary due to power line variations the torque produced would consequently vary, and if not compensated for would unsettle the compass. The method used to compensate for power line variations is to compensate the excitation voltages of the signal sources. This compensation is such that the excitation voltages are changed by the same percentage as any power line change but in the opposite sense. If the power line voltage drops, the excitation voltage rises. The net result is that the torque produced by the torquers is constant.

The 115-volt 400-cycle power line voltage is impressed across the series circuit in the voltage compensator consisting of resistors R319 and R333, and ballast current regulating tube V306 (fig. 13-9). Because of the constant current design of the tube, the voltage across the series resistors remains constant. The voltage change across V306 is the same as the voltage change of the power line. The voltage across V306 is impressed on the primary of the stepdown transformer T301. The voltage across the secondary of transformer T301 is subtracted from the constant voltage drop across the series resistors and the difference is impressed on the primary of excitation transformer T302. The output from the secondary of T302 is fed to the various correction circuits. If the power line voltage drops, the voltage across V306 and, therefore, the voltages across the primary and secondary of T301 must drop. The voltage across resistors R319 and R333 however, remains constant. This means the sum of the voltage drops across the secondary of T301 and the primary of T302 must equal the voltage drop across R319 and R333. For this condition to exist the voltage across the primary of T302 must increase when the voltage across the secondary of T301 decreases. Resistor R319 is adjustable to provide a method of calibrating or adjusting the circuit. The indicator lamp I302, connected across V306 is a neon corrector failure indicator. When the circuit is operating properly, the voltage across the lamp will not be sufficient to cause the lamp to glow; however, if the ballast tube fails, the voltage across the lamp will rise and light the lamp. In addition the compensator has an alarm output voltage to an alarm relay in the compass alarm system. The relay is operated by the voltage developed across resistors R319 and R333 which is about 70 volts during normal operation. Failure of the ballast tube or power line supply causes the relay to drop out and sound the alarm. The voltage compensator supplies excitation voltage for all compass control signals except the tilt signal from the electrolytic bubble level. The tilt signal is normally zero while the other signals have a definite value other than zero.

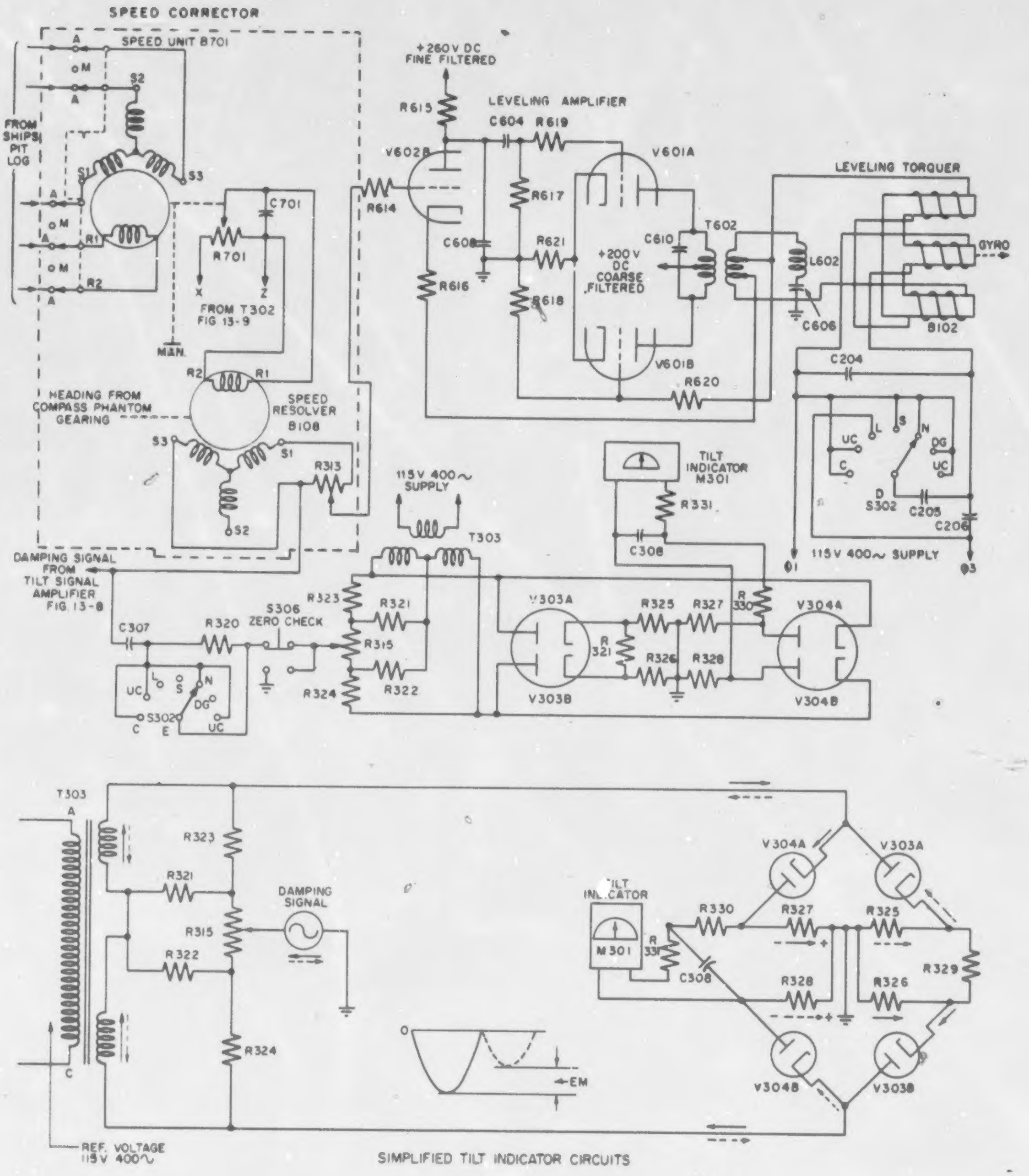
The azimuth control amplifier mixes three input signals, amplifies the combined signal, and supplies the control fields of the azimuth control torquers. The amplifier (fig. 13-9) consists of a triode input stage driving a push-pull output stage. Three signal voltages are fed through mixing resistors so that the resultant input signal to the V602A grid is the meridian control signal compensated for compass mechanical unbalance, vertical earth rate, and latitude. Capacitor C607 connected from the plate of V602A to ground limits the high frequency response of the amplifier and provides increased stability.

The output stage consists of two pentodes V603 and V604 connected in push-pull. Output transformer T601 is used to match the impedance of the output stage to the tuned impedance of the series connected control fields of the azimuth control torquers.

Capacitor C605 in series with L601 across the secondary of T601 corrects the power factor of the torquer load, and the inductor L601 alters the frequency characteristic of the amplifier and ensures stability. A negative feedback voltage is taken from a tap on the secondary of the output transformer and is fed back to the V602A cathode. This feedback keeps the overall voltage gain of the amplifier to 2 and the maximum power output to 5.5 watts.

The azimuth control torquers are the output elements of the azimuth control system which actually apply torques about the gyro horizontal axis causing precession about the vertical axis or causing the gyro to turn in azimuth toward the meridian. The torquers are located diametrically opposite each other on the adapter ring, and are electrically connected to act together to produce the torque.

Each torquer consists of an open-E rack structure of soft iron laminations, upon which are wound a control field (on the 2 outer legs) and a fixed or reference field (on the center


SPEED CORRECTOR
SPEED UNIT B701
FROM SHIPS PIT LOG
S1
S2
S3
R1
R2
A
M
C701
R701
X
Z
FROM T302 FIG 13-9
MAN.
HEADING FROM COMPASS PHANTOM GEARING
SPEED RESOLVER B108
R313
+260V DC FINE FILTERED
R615
LEVELING AMPLIFIER
C604
R619
V602B
V601A
R614
R617
C608
R621
R616
R618
+200V DC COARSE FILTERED
C610
T602
L602
C606
V601B
R620
LEVELING TORQUER
GYRO
B102
C204
UC
L
S
N
DG
C
D
S302
C205
C206
115V 400~ SUPPLY
Ø1
Ø3
TILT INDICATOR M301
R331
C308
115V 400~ SUPPLY
T303
DAMPING SIGNAL FROM TILT SIGNAL AMPLIFIER FIG. 13-8
C307
R320
S306 ZERO CHECK
R323
R321
R315
R322
R324
E
V303A
V303B
R325
R327
R321
R326
R328
R 330
V304A
V304B
T303
A
C
DAMPING SIGNAL
REF. VOLTAGE 115V 400~
O
EM
TILT INDICATOR
M301
R 331
C308
R330
R327
R325
R328
R326
R329
SIMPLIFIED TILT INDICATOR CIRCUITS

27.164

Figure 13-10.—Simplified schematic diagram of leveling control system and tilt indicator.

leg) displaced 90 degrees to form an arrangement similar to a 2-phase induction motor. The control fields are excited from the azimuth control amplfier output and the fixed or reference fields are excited from the 115-volt 400-cycle supply. When the torquer windings are energized, a moving field is set up in the air gap. This field induces currents in the vertical ring and a torque is developed that tends to drag the vertical ring along with the moving field. The magnitude of the torque is proportional to the strength of the signal fed to the control windings, and the direction of the torque depends upon the phasing of the control field voltage which may lead or lag the fixed field voltage by 90 electrical degrees. To obtain the correct phase relationship between the control and fixed fields, capacitors C207 and C208 shift the phase of the fixed field.

LEVELING CONTROL SYSTEM

The leveling control system (fig. 13-10) consists of the speed corrector, the leveling amplifier, and leveling torquer. The system functions to apply a torque about the gyro vertical axis causing the gyro to assume a level position.

If a ship is traveling on a north-south course, as it follows the curvature of the earth, the north end of the gyro would appear to tilt. For a northerly course, the resultant tilt signal will cause the gyro to precess to the west, while a southerly course will cause precession in the opposite direction. If the ship's course is east-west, however, the ship's motion would have no tendency to tilt the gyro as the ship's direction of travel would be parallel to the plane of the gyro. The rate of gyro tilt depends upon the speed of the ship in a northerly or southerly direction, and is equal to the ship's speed times the cosine of the ship's course. This tilt is compensated for in the Mk23 gyrocompass. by the speed corrector, which consists of a speed unit B701, and speed resolver B108, (fig. 13-10).

The speed unit consists of a synchro geared to potentiometer R701. Potentiometer R701 is a precision linear potentiometer excited with a fixed excitation voltage from the output of transformer T302 in the voltage compensator, (fig. 13-9). For automatic operation, the synchro receives the ship's speed input from the pitometer log system, and positions potentiometer R701 which results in a voltage drop, proportional to ship's speed, across R701. A portion of this voltage is impressed on the rotor of the resolver, B108. For manual operation the input from the pitometer log is disconnected and the ship's speed is cranked in manually by the manual control knob.

The rotor of the speed resolver is positioned by the azimuth gear on the phantom, and thus represents the ship's heading. The resolver then functions to resolve the magnitude of the voltage on its rotor representing ship's speed into it's northerly or southerly component. Thus the resolver output (between S1 and S3) is a voltage proportional to northerly or southerly speed.

Potentiometer R313 provides a method of adjusting the resolver output and is a factory adjustment. Capacitor C701 serves to correct the power factor of the speed signal.

The leveling amplifier (fig. 13-10) is similar to the azimuth control amplifier. It functions to amplify the damping signal and supply the control field of the leveling torquer.

The amplifier input is the damping signal from the tilt signal amplifier, compensated for northerly or southerly speed, and is fed through resistor R614 to the grid of V602B.

The output stage consists of the dual triode V601A and B. Output section V601A is excited from the output of V602B and V601B is excited from the secondary of output transformer T602.

The use of part of the output from the transformer to excite V601B produces the proper phase inversion for push-pull operation. Output transformer T602 also serves to match the impedance of the output stage to the tuned impedance of the leveling torquer control field.

Power factor correction and frequency characteristic alteration are accomplished by capacitor C606 and inductor L602 across the secondary of output transformer T602. A portion of the output is fed back as negative feedback to the input stage V602B. The magnitude of the feedback limits the amplifier voltage gain to 1, with an output power of 1.5 watts.

The leveling torquer is the output element that actually produces the torque about the gyro vertical axis, causing the gyro to assume a level position. It is mounted on the horizontal part of the vertical ring. It is a duplicate of the azimuth control torquers, and operates in the same manner.

To reduce the time required to level the gyro during the starting period, operation switch S302D, in conjunction with capacitors C204, 205, and 206, increase the leveling torquer fixed field voltage. In all positions, except the level position, the operation switch connects capacitors C204 and C205 in parallel across the torquer fixed field. This arrangement produces about 6 volts across the field with a 90-degree phase shift. With the operation switch in the level position, capacitor C205 is connected in parallel with capacitor C206 and both are in series with the fixed field. This connection produces about 60 volts across the fixed field, with the same 90-degree phase shift.

During starting and operating, a visual indication of the gyro tilt is desirable. As the compass level cannot be seen when the compass is assembled, a tilt indicator meter is provided on the front of the control panel.

To detect the direction of tilt, a full-wave diode phase sensitive demodulator circuit is used as shown in figure 13-10. The circuit may be considered to be composed of two half-wave sections, using the reference transformer T303 with resistor network R321, R322, R323 and R324 and balance potentiometer R315 for both half-wave sections. The input is the damping signal from the tilt signal amplifier and is applied effectively between the center tap of the diode load resistors and the center tap of the reference voltage transformer through balance potentiometer R315. The signal is either in phase or 180° out of phase with the reference voltage.

If the input signal is zero (gyro level) the output voltage of the demodulator section (to the tilt indicator) will also be zero. If an input signal is in phase or adding to the a-c reference voltage applied to V304A, it will subtract from the a-c reference voltage applied to V304B. Tube section V304A therefore will conduct more current. The voltage drop across the meter on one half cycle will be greater than that on the next half cycle, and the net d-c output voltage will be proportional to the a-c signal voltage. If the phase of the signal voltage is reversed, the polarity of the d-c output voltage will reverse.

As the voltage gain of the tilt signal amplifier is altered during certain operating modes, operations switch S302E shorts resistor R320 during the low gain periods, thus keeping the tilt meter calibration the same for both high and low amplifier gain.

Zero switch S306 is used to short the input signal to the tilt indicator circuit for calibrating and zeroing the tilt meter.

FOLLOWUP SYSTEM

The followup system functions to drive the phantom bowl in azimuth, so that the vertical ring is continuously aligned with the plane of the gyro. The system is a closed-loop servosystem in which a followup pickoff device between the vertical ring and gyrosphere provides a misalignment signal to a followup amplifier. The followup amplifier amplifies the signal and operates the followup or azimuth motor which drives the phantom, and therefore the vertical ring, into alignment with the gyrosphere. The followup motor driving through the azimuth gearing also positions the synchro heading data transmitter and the speed resolver as indicated in figure 13-7.

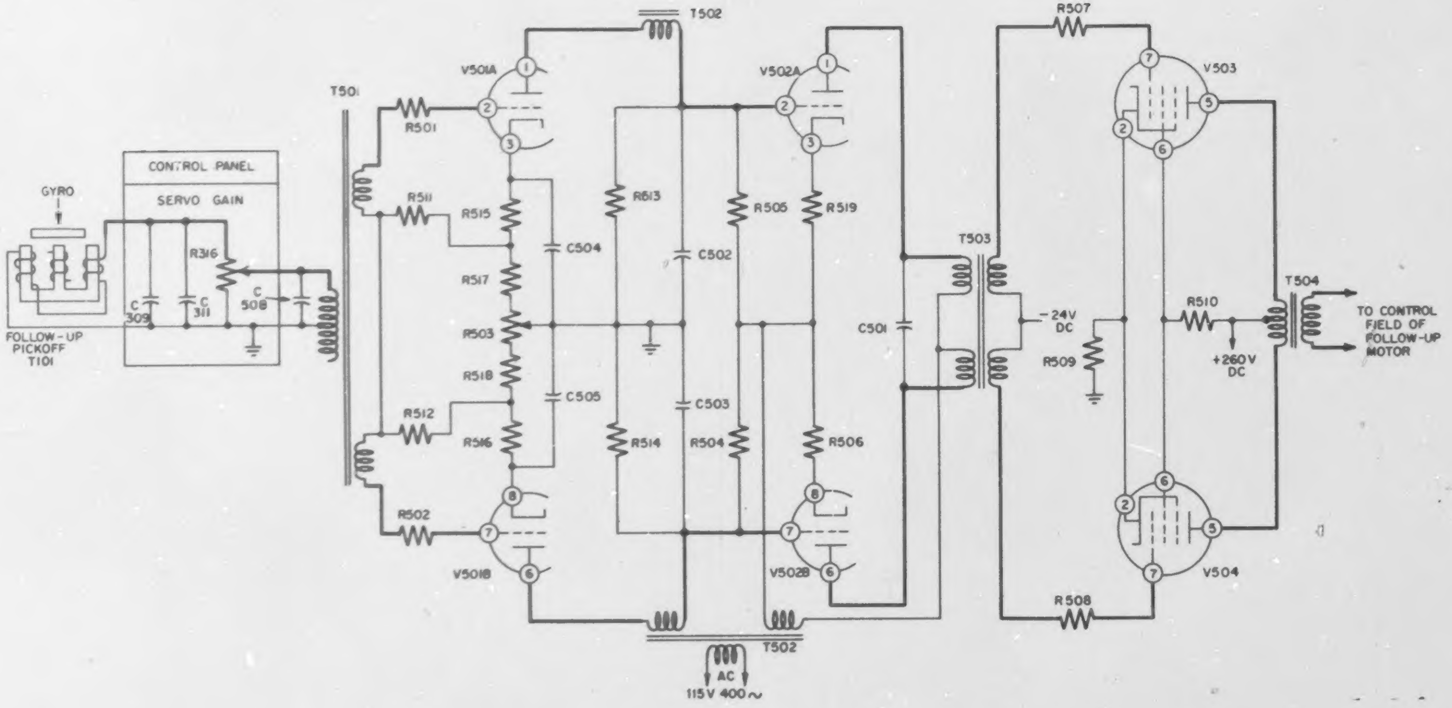
The system consists of the followup pickoff, followup motor, followup amplifier, manual azimuth controls and followup alarm.

The followup pickoff consists of an E core followup transformer mounted on a horizontal portion of the vertical ring under the electrolytic bubble level, and a ferramic armature cemented to the gyrosphere, that bridges the E core gap. The followup pickoff is constructed in the same manner and its operation is identical to the followup transformer described in the preceding chapter. The followup transformer primary, on the E core center leg, is excited from the output of excitation transformer T102 the same transformer used to excite the electrolytic bubble level.

The followup motor is mounted on the spider and geared to the azimuth gear on the phantom. It is a 2-phase 4-pole induction motor having a fixed field connected to one phase of the 115-volt 400-cycle supply through a capacitance network which gives a 90-degree phase relationship between the fixed and control field. The direction of rotation depends upon the instantaneous polarity of the signal from the followup amplifier with respect to that of the control field, and the speed of rotation depends upon the magnitude of the signal, or the amount of displacement between the vertical ring and gyrosphere.

The followup amplifier provides the required voltage and power amplification to the followup pickoff signal to operate the followup motor as previously indicated. In addition it provides the required stabilization for the followup system.

The amplifier (fig. 13-11) consists of a half-wave phase sensitive demodulator input stage, V501A and B, employing a feedback loop to rate and displacement networks for system stabilization, a half-wave modulator second stage, V502A and B, and a push-pull output stage, V503 and V504.


GYRO
FOLLOW-UP PICKOFF T101
CONTROL PANEL
SERVO GAIN
R316
C 309
C 311
C 508
T501
R501
R511
R512
R502
V501A
V501B
R515
R517
R503
R518
R516
C504
C505
T502
R613
R514
C502
C503
R505
R504
V502A
V502B
R519
R506
AC
115V 400~
C501
T503
-24V DC
R509
R507
R508
V503
V504
R510
+260V DC
T504
TO CONTROL FIELD OF FOLLOW-UP MOTOR

7.186

Figure 13-11.—Simplified schematic diagram of followup amplifier

The followup pickoff signal is fed to the primary of input transformer T501 and is stepped up by a ratio of 10 to 1. The secondaries feed the stepped up signal to the grids of the twin-triode demodulator tube sections. Each tube receives the same magnitude signal but opposite in phase. Series grid resistors R501 and R502 prevent loading the input transformer and provides tube protection on positive grid excursions. The plates of the demodulator tube are excited with a 400-cycle voltage obtained from the plate reference transformer T502, phased so that the plates of both tubes are positive or negative at the same time. (Note upper and lower plate windings of T502). This voltage is phase-locked with the excitation voltage of the followup pickoff. Thus, the followup signal voltage is either in phase or 180 degrees out of phase, with the voltage applied to the plates of V501A and B, depending upon the direction of the displacement between the vertical ring and gyrosphere. As current flows through the tube only during the positive plate excursion, the output of each tube section is a half-wave rectified current. A d-c voltage is developed across R504 and R505 proportional to the magnitude of the followup pickoff signal, with its polarity dependent upon the phase of the pickoff signal. Capacitors C502 and C503 serve to suppress the harmonics and smooth the rectified half-wave d-c signal. A negative feedback signal across R519 and R506 in the modulator stage V502A and B, required for the stabilization of the control loop, is generated from this d-c voltage.

A network in the positive feedback loop of V501A and B serves to produce a signal, proportional to the rate of change of the followup pickoff signal, for momentarily increasing the demodulator gain. This network, called a rate circuit, enables a servo to overcome the effect of inertia in the moving parts of the followup system. The effect of the rate signal is to prevent a large momentary displacement between the pickoff and the gyrosphere.

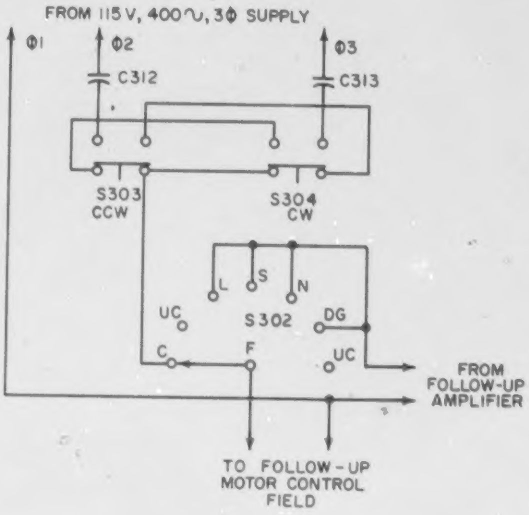
For most effective servo control it is necessary to combine displacement and rate signals. Two circuits combining these signals are used in the demodulator stage. The feedback loop for V501A consists of part of potentiometer R503 resistors R517, R515, and R511, and capacitor C504. The feedback loop for V501B consists of part of potentiometer R503 resistors R518, R516, and R512 and capacitor C505.

The d-c output voltage of the demodulator stage is applied to the grids of the half-wave modulator tube sections V502A and B. The plates of each half of the tube are connected to opposite ends of the center-tapped primary winding of modulator transformer T503. The center tap of this winding is connected to the 400-cycle reference voltage obtained from one winding of the plate reference transformer T502. As the plates are excited through the center tap of transformer T503, the two sections conduct at the same time during their positive voltage excursions.

If the input voltage is zero, V502A and B conduct the same amount of current. The current from V502A through the primary of T503 is opposite to that from V502B, therefore the secondary output of T503 is zero.

The output voltage of the modulator is applied to the grids of the push-pull power output tubes, V503 and V504. Transformer T504 is the output transformer and matches the plate impedance of V503 and V504 to the tuned impedance of the followup motor.

All plate voltages, the bias voltage for the output stage, and the filament voltages are obtained from the d-c power supply in the control

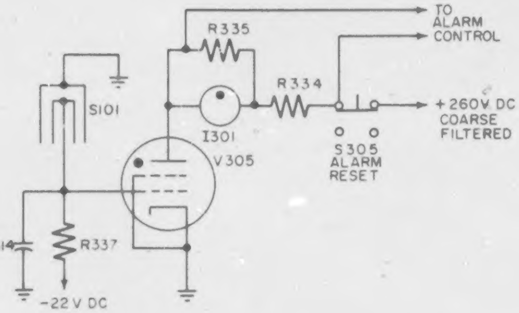


27.166
Figure 13-12.—Simplified schematic diagram of manual azimuth control circuit.

cabinet. Capacitors C309, C311, and C508 serve as phase shift correction for the pickoff signal. Potentiometer R316 at the T501 input is the servo gain adjustment.

A manual azimuth control circuit (fig. 13-12) is provided for slewing the sensitive element in azimuth to the meridian when starting. This allows the compass to settle on the meridian in a minimum time. The manual azimuth switches S303 and S304 are connected to the followup motor control field when operation switch S302 is in the cage position. The voltage applied to the control field is obtained from the 115-volt 400-cycle 3-phase supply. Capacitors C312 and C313 provide the correct voltage and also the necessary phase shift, with respect to the fixed field, to drive the motor. Switch S303 applies voltage to the control field, phased properly to slew the compass in a counterclockwise direction and switch S304 applies voltage 180 degrees out of phase, to slew in a clockwise direction.

The movement in azimuth of the sensitive element with respect to the phantom is restricted to about ±8 degrees by mechanical limit stops. To indicate when the phantom reaches this limit, a followup failure alarm circuit (fig. 13-13) is provided. The circuit consists of a followup failure switch S101, a thyratron tube, V305, and a neon followup failure indicator light, I301.



27.167
Figure 13-13.—Simplified schematic diagram of followup alarm circuit.

The followup failure switch is mounted on the vertical ring and consists of two fine V- shaped wires insulated from each other. An actuator on the equatorial band of the gyrosphere (fig. 13-3) shorts the two wires when the limits of travel are reached.

Thyratron V305 has its grid connected to the negative bias supply through resistor R337. The plate is connected to a positive 260-volt coarse-filtered direct current through the indicator lamp series resistor R334 and normally closed alarm reset contacts. One of the V-shaped wires of S101 is connected to the V305 grid and the other to the d-c common (ground).

Under normal conditions the thyratron is biased so no plate current will flow. When switch S101 is actuated, the grid will be connected to the d-c common, removing the bias, causing the thyratron to fire. The indicator lamp I301 will glow, and the voltage output to the alarm control energizes an alarm relay to actuate the alarm. The thyratron will continue to conduct until the alarm reset button is pushed, removing the plate voltage.

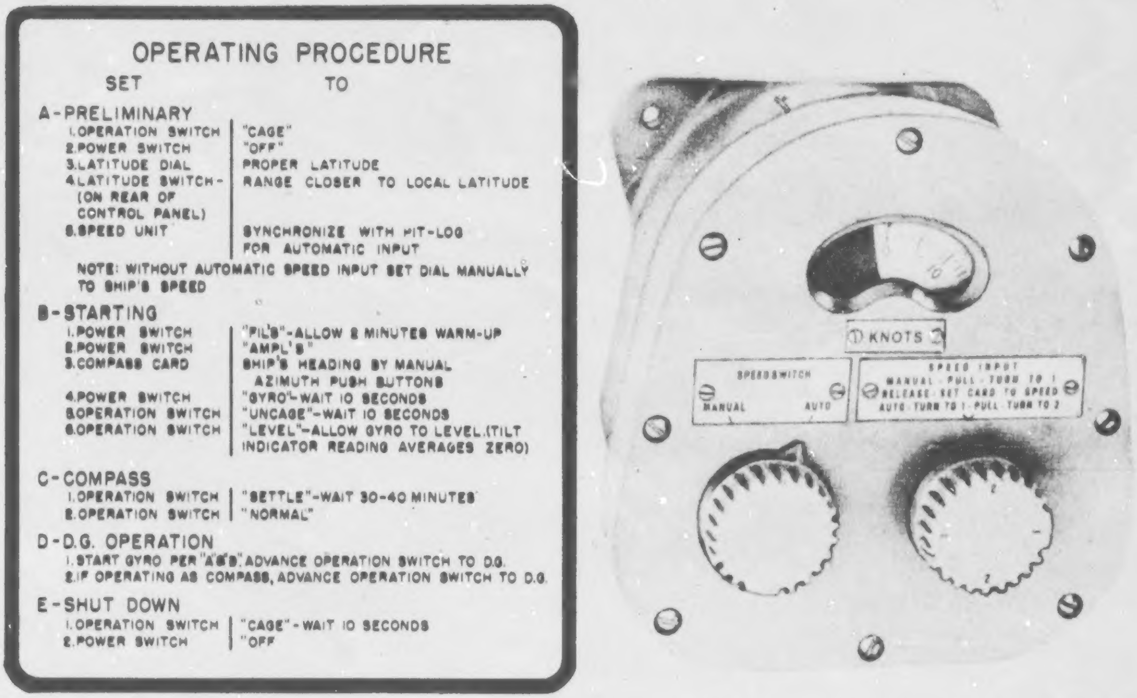
Resistor R335 across the neon failure lamp is used to ensure that the lamp will glow when the thyratron fires.

OPERATION

The operating procedure for the Sperry Mk 23 gyrocompass is summarized on the starting instruction plate (fig. 13-14) located on the front of the control cabinet (fig. 13-1). Normally the compass should be started at least two hours before it is needed for service.

If it becomes necessary to stop the compass in a heavy sea for any reason, other than failure of the followup system, the following procedure should be followed:

1. Place the power switch in the AMPL's position.
2. Wait 30 minutes then place the operation switch in the CAGE position.
3. Place the power switch in the OFF position. In case of followup system failure, place the operation switch in the CAGE position immediately, and the power switch in the OFF position.



OPERATING PROCEDURE

SET	TO
A-PRELIMINARY	
1. OPERATION SWITCH	"CAGE"
2. POWER SWITCH	"OFF"
3. LATITUDE DIAL	PROPER LATITUDE
4. LATITUDE SWITCH-(ON REAR OF CONTROL PANEL)	RANGE CLOSER TO LOCAL LATITUDE
5. SPEED UNIT	SYNCHRONIZE WITH PIT-LOG FOR AUTOMATIC INPUT

NOTE: WITHOUT AUTOMATIC SPEED INPUT SET DIAL MANUALLY TO SHIP'S SPEED

SET	TO
B-STARTING	
1. POWER SWITCH	"FIL'S"-ALLOW 2 MINUTES WARM-UP
2. POWER SWITCH	"AMPL'S"
3. COMPASS CARD	SHIP'S HEADING BY MANUAL AZIMUTH PUSH BUTTONS
4. POWER SWITCH	"GYRO"-WAIT 10 SECONDS
5. OPERATION SWITCH	"UNCAGE"-WAIT 10 SECONDS
6. OPERATION SWITCH	"LEVEL"-ALLOW GYRO TO LEVEL. (TILT INDICATOR READING AVERAGES ZERO)
C-COMPASS	
1. OPERATION SWITCH	"SETTLE"-WAIT 30-40 MINUTES
2. OPERATION SWITCH	"NORMAL"

D-D.G. OPERATION

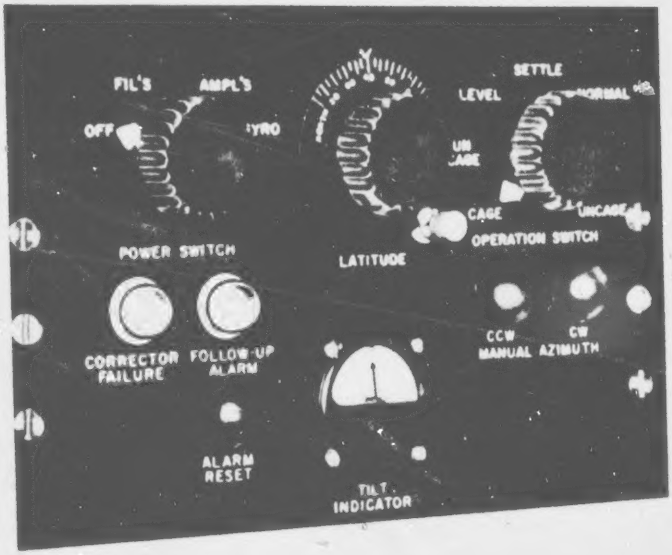
1. START GYRO PER "A&B", ADVANCE OPERATION SWITCH TO D.G.
2. IF OPERATING AS COMPASS, ADVANCE OPERATION SWITCH TO D.G.

SET	TO
E-SHUT DOWN	
1. OPERATION SWITCH	"CAGE"-WAIT 10 SECONDS
2. POWER SWITCH	"OFF"

KNOTS
SPEED SWITCH
MANUAL
AUTO
SPEED INPUT
MANUAL - PULL - TURN TO 1
RELEASE - SET CARD TO SPEED
AUTO - TURN TO 1 - PULL - TURN TO 2

STARTING INSTRUCTION PLATE

SPEED UNIT SHOWING CONTROLS

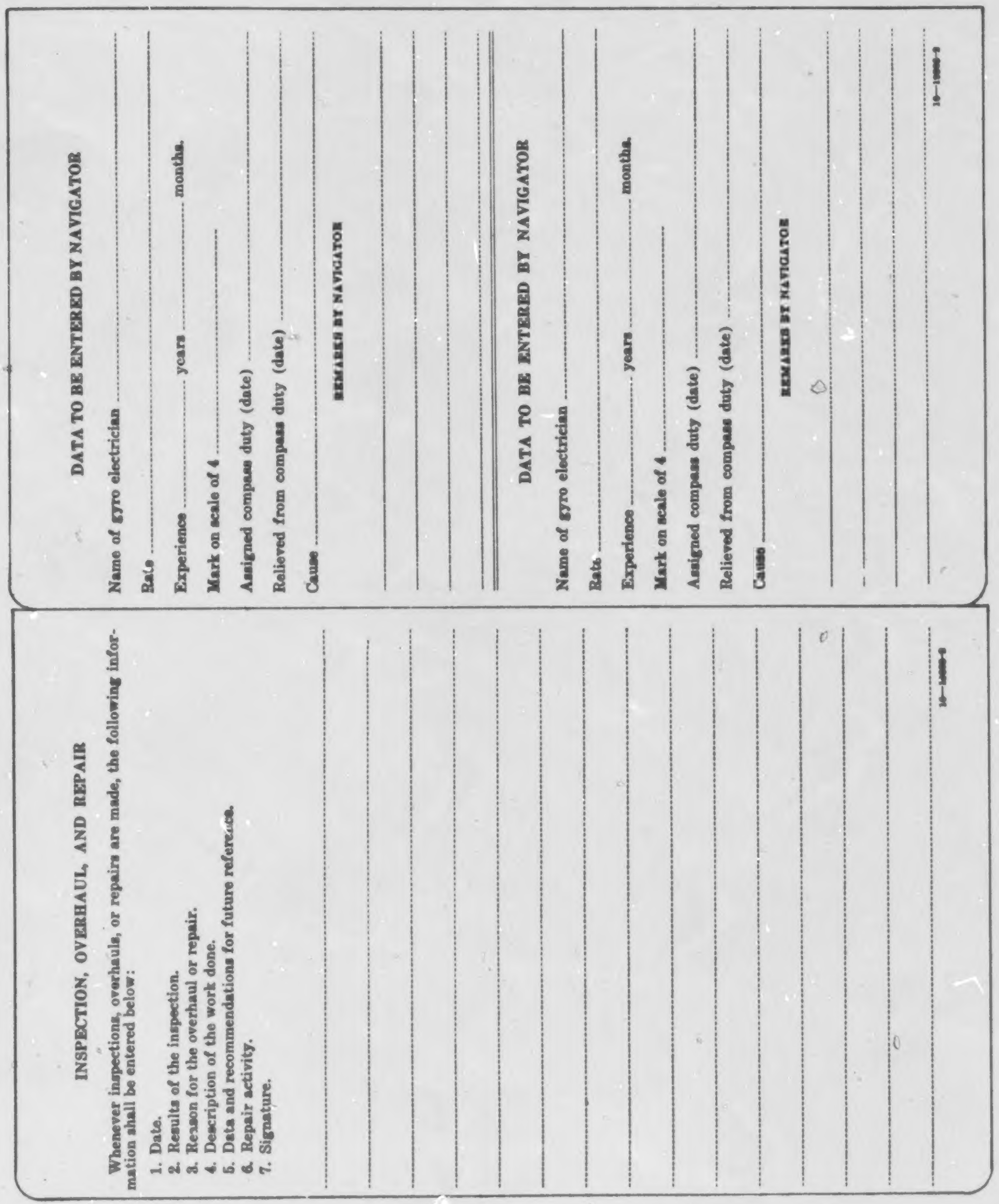


FIL'S
AMPL'S
OFF
GYRO
LEVEL
SETTLE
NORMAL
UNCAGE
CAGE
UNCAGE
OPERATION SWITCH
POWER SWITCH
LATITUDE
CORRECTOR FAILURE
FOLLOW-UP ALARM
CCW
CW
MANUAL AZIMUTH
ALARM RESET
TILT INDICATOR

CONTROL PANEL

77.225

Figure 13-14.—Operating procedure and controls, Sperry Mk 23 Mod 0 Gyrocompass.



DATA TO BE ENTERED BY NAVIGATOR

Name of gyro electrician ....

Rate ....

Experience .... years .... months.

Mark on scale of 4 ....

Assigned compass duty (date) ....

Relieved from compass duty (date) ....

Cause ....

REMARKS BY NAVIGATOR

DATA TO BE ENTERED BY NAVIGATOR

Name of gyro electrician ....

Rate ....

Experience .... years .... months.

Mark on scale of 4 ....

Assigned compass duty (date) ....

Relieved from compass duty (date) ....

Cause ....

REMARKS BY NAVIGATOR

INSPECTION, OVERHAUL, AND REPAIR

Whenever inspections, overhauls, or repairs are made, the following information shall be entered below:

1. Date.
2. Results of the inspection.
3. Reason for the overhaul or repair.
4. Description of the work done.
5. Data and recommendations for future reference.
6. Repair activity.
7. Signature.

140.141

Figure 13-15.—Gyrocompass service record book page.

If power to the compass fails, place the power switch in the FIL's position and the operation switch in the CAGE position. When the power is restored, restart the compass in the usual manner.

Setting Correction Devices

Correction device settings for the Mk 23 gyrocompass include the manual speed setting on the speed unit, the latitude control knob setting on the control panel, and the latitude switch setting on the rear of the control panel.

When operating the speed unit manually, adjust the speed settings to correspond to the average ship's speed. Change the latitude control knob setting on the control panel when the ship's latitude changes as much as two degrees or as ordered by the ship's navigator. Throw the latitude switch on the rear of the control panel to the 65 degree position for normal operation when the ship's latitude is above 60 degrees. The position of the latitude switch is immaterial for directional gyro operation.

Indications of Normal Operation

Normal operating conditions for the compass are indicated by the following:

1. The followup failure and corrector failure lamps on the control panel (fig. 13-14), should be dark.
2. The master unit should be lukewarm.
3. The speed dial should indicate the ship's speed for normal operation or zero for directional gyro operation.
4. The tilt indicator pointer should be oscillating evenly about the zero position.

MAINTENANCE

Routing maintenance instructions for an installed gyrocompass are part of both the Planned Maintenance Subsystem and the manufacturer's technical manual. This manual also contains corrective maintenance procedures and troubleshooting hints. The key to troubleshooting and repairing the gyrocompass is to follow the step-by-step methods as outlined.

GYRO RECORDS AND LOG ENTRIES

As an IC Electrician you will be keeping records on the gyrocompass and other major pieces of IC equipment, also making entries in a gyro logbook. A service record book is furnished with each gyrocompass installed aboardship. As the gyro electrician you enter in this book information concerning inspections, overhauls, and repairs to the gyrocompass. Each page of the book shows seven items of information that you must record for each inspection, overhaul, or repair. See figure 3-15. This figure also shows the kinds of data that the ship's navigator can enter in the gyro record book. His signature is proof that he has read the entries in the record book.

In addition to the service record book, most ships have a daily gyro log sheet that is filled out on the hour by the watchstander. His entries show the conditions of the gyrocompass and the power sources available. These entries are checked the next day for accuracy and neatness by the leading petty officer.

SYNCHRO SIGNAL AMPLIFIERS

Synchro signal amplifiers are used to reduce the size of synchro transmitters in gyrocompasses, wind indicators and other sensing devices that are more accurate if there is only a small load on their outputs. Synchro signal amplifiers must meet some or all of the following operational requirements.

- Accept a low current synchro signal, amplify the signal, and use the amplified signal to drive large capacity synchro transmitters.

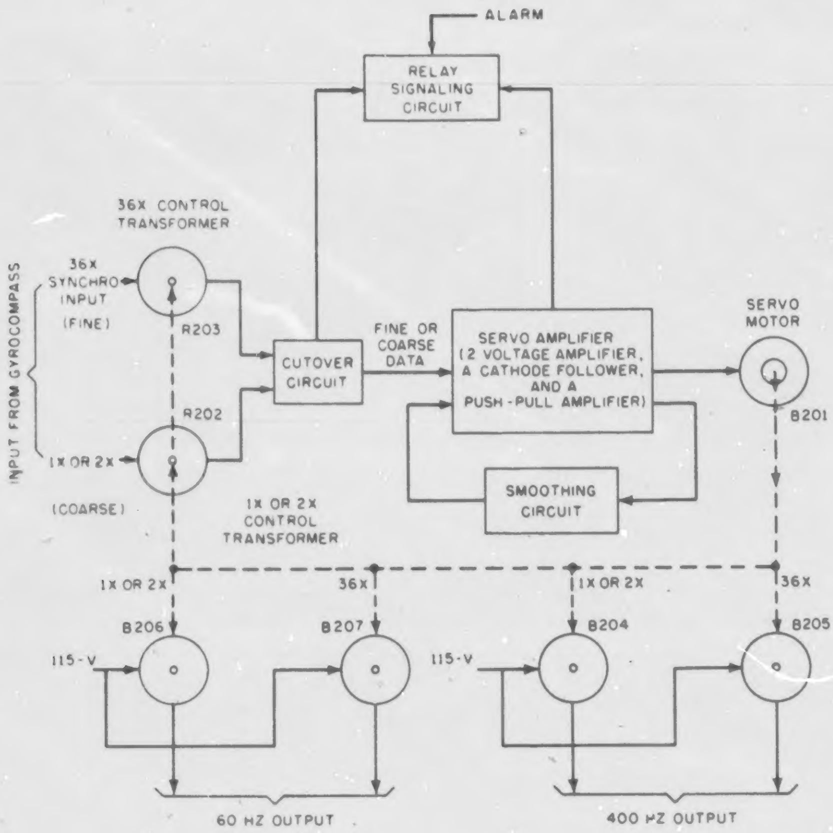
- Isolate oscillations in a synchro load which may be reflected from the input signal bus.

- Permit operation of a synchro load independent of the input synchro excitation.

- Provide multiple channel output transmission of a single channel input signal.

- Permit operation of a synchro load independent of the input synchro excitation.

Figure 13-16 is a block diagram of a basic synchro signal amplifier. The input signals may be derived from any number of sources, but the most common application is in gyrocompass transmission. From the compass, information is sent out through a dual-speed synchro system. This system uses two transmitters and two receivers. One transmitter receives the input to the system, and passes the input signal to


ALARM
RELAY SIGNALING CIRCUIT
36X CONTROL TRANSFORMER
36X SYNCHRO INPUT (FINE)
INPUT FROM GYROCOMPASS
R203
R202
1X OR 2X
(COARSE)
1X OR 2X CONTROL TRANSFORMER
CUTOVER CIRCUIT
FINE OR COARSE DATA
SERVO AMPLIFIER (2 VOLTAGE AMPLIFIER, A CATHODE FOLLOWER, AND A PUSH-PULL AMPLIFIER)
SERVO MOTOR
B201
SMOOTHING CIRCUIT
1X OR 2X
36X
1X OR 2X
36X
B206
B207
B204
B205
115-V
115-V
60 HZ OUTPUT
400 HZ OUTPUT

140.131

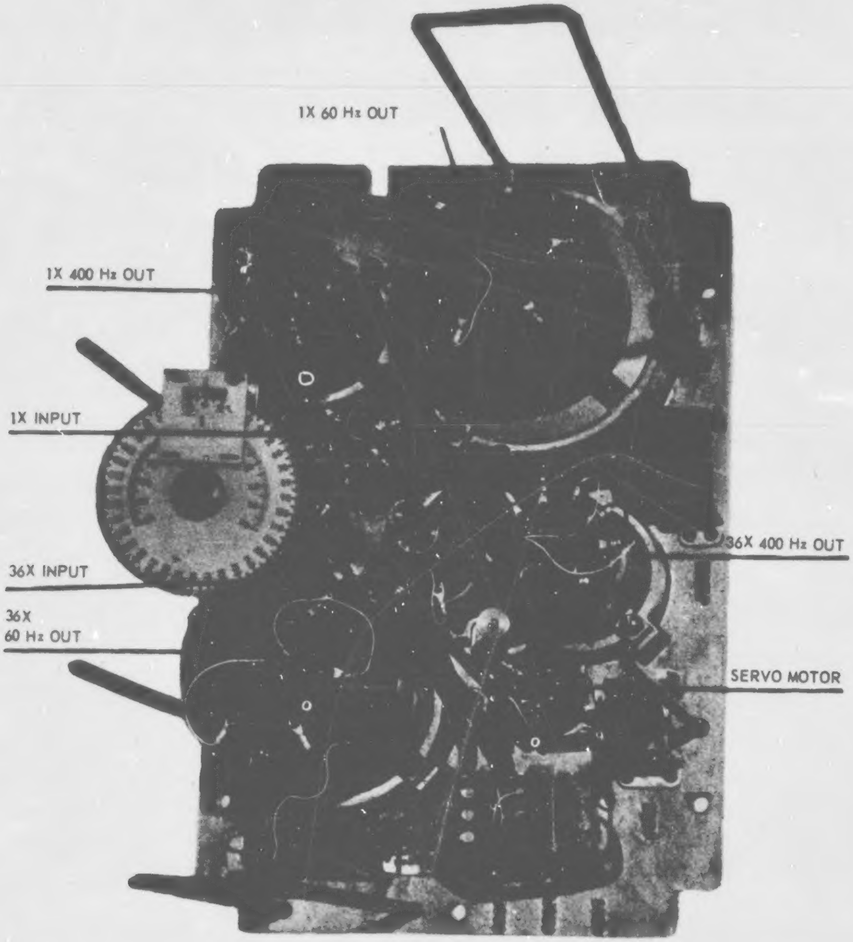
Figure 13-16.—Block diagram of synchro signal amplifier.

the second transmitter through a gear train. The ratio of the gear train will determine the two specific "speeds" which the system will use to transmit data. In this case the ratio is 1:36, so both single and X 36-speed information is sent to the control transformers in the amplifier. The control transformers compare the input and output signals and produce error signals. The fine error signal will have 36 times the angular displacement of the coarse signal. In tracing the signal in figure 13-16 the next component the signal goes to is the cutover circuit. This cutover circuit will normally select the 36-speed input. But when the output signal is more than 2.5 degrees out of correspondence with the input signal, the cutover circuit will switch to the coarse, or single speed, information. Whichever signal is selected by the cutover circuit is the error signal. It is amplified by vacuum tube amplifiers, magnetic amplifiers, or transistor amplifiers. The amplified signal that goes to one stator coil of the servo motor. The motor turns, driving the retransmitting synchros until their output matches the input, and there is no signal from the control transformers.

The synchro amplifier in figure 13-16 can provide signals to 400-Hz and 60-Hz equipment by using two sets of synchro transmitters and the necessary two power supplies.

ELECTRONIC COMPONENT

The electronic component contains the cutover circuit, relay signaling circuit, servo amplifier with negative feedback, and transformer coupling to the servo motor in the electromechanical unit.



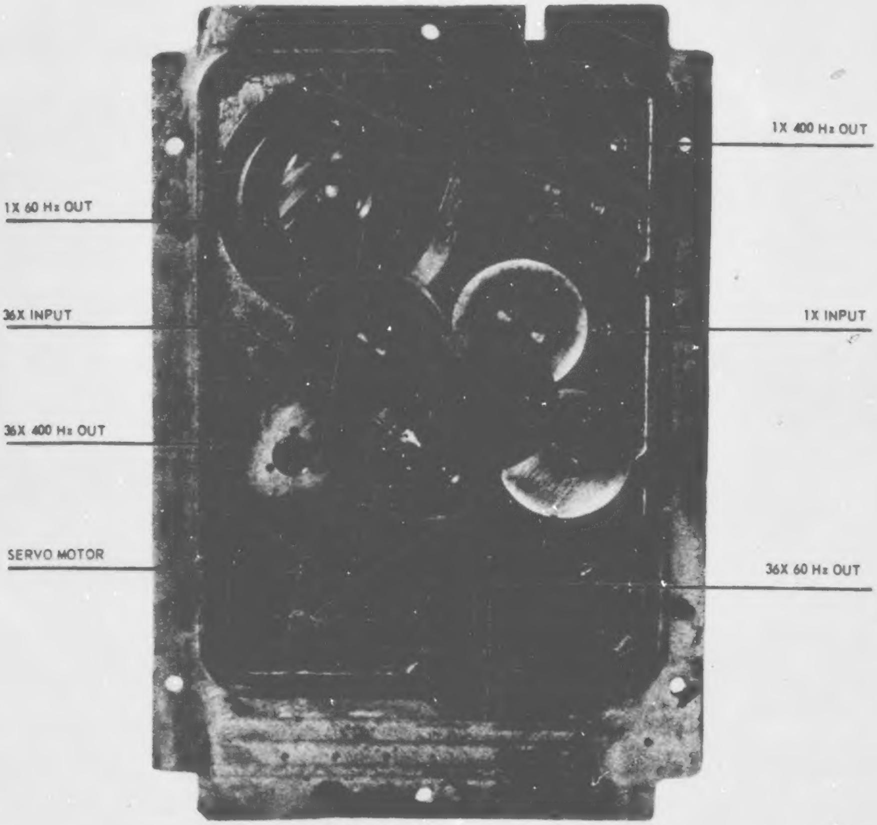
40.132.1

Figure 13-17A. — Mechanical unit (top view).

The input signal to be amplified is selected by the cutover circuit. The cutover is basically a relay that will switch from the fine, or 36 speed signal to the coarse signal when the coarse signal reaches a certain strength. Figure 13-16 shows the basic concept of the cutover circuit. The signal then undergoes two stages of amplification. These stages incorporate a cathode follower phase splitting network or some other means of damping out electrical oscillations. After the first two stages of amplification the signal drives a push-pull output amplifier, which produces the control current for the servo motor in the electromechanical unit.

ELECTROMECHANICAL UNIT

Figure 13-17 shows the top and bottom of the electromechanical unit of a synchro amplifier. Notice the two input control transformers (1X and 36X) the rotors of which are positioned mechanically by the gear train on the bottom of the unit. The difference between the rotor angles of the control transformers and the electrical angles of the input signals cause error voltages to be generated in the control transformer rotor windings. These signals go to the electronic unit just discussed, where one of them is amplified to become the control current in the servo motor.



40.132.2

Figure 13-17B.—Mechanical unit (bottom view).

The control current causes the servo motor to operate to drive the gear train until the rotor angles and electrical angles of the input control transformers are the same, and there is no error signal.

The servo motor is a two-phase, low inertia, induction motor. One of its two stator coils is connected to the a-c line. The other stator coil receives the control current from the amplifier. Inductors and capacitors, alone or in combination are used to displace the electrical angle of the control current 90° from the reference current. The control current from the amplifier has the direction of the initial error signal, so this current will cause the servo motor to rotate in the proper direction to correct the error, and vary the speed of the motor in proportion to the amount of error.

Because of the gear train that connects the input and output synchro units, as the servo motor drives the input control transformers to their null or zero error signal position, it also positions the output synchros to retransmit or repeat the original signal. The output synchros may be either synchro transmitters or differential generators. As you can see from figures 13-17A and 13-17B coarse and fine outputs for both 60-Hz and 400-Hz systems are available from the one synchro signal amplifier. If differential generators are used for the output, they will transmit the sum or difference of the original signal, and a synchro signal from another source.

STICKOFF CURRENT

A control transformer will produce zero error signal both at the angle of correspondence between synchro signal and rotor position, and also at 180° out of correspondence. This is not a great problem in a two-speed synchro system such as the one described, since the single- or 2-speed unit will register an error even when the 36-speed unit is "hung up" approximately 180° out of phase. However, if the coarse unit is exactly 180° out of phase, the fine unit will also be 180° out of phase. To prevent the system from locking onto a 180° error, a stickoff current is applied to the coarse control transformer.

The effect of adding a small current to the rotor of the control transformer is to offset the point at which it will not generate an error signal. If this offset amounts to 2.5° in one direction, the rotor zero position is offset 2.5° in the opposite direction. When this is done, the single speed control transformer will produce a zero error when its position corresponds to the input signal, but will show an error when 180° out of correspondence. There will be a null position at 175° or 185°, but at these points the fine, or 36-speed CT is indicating an error and will drive the system.

FREQUENCY OF INPUT SIGNAL

The synchro signal amplifier just discussed can be used on 400-Hz or 60-Hz input power source, signals, and reference voltages by changing some of the resistors and capacitors in the circuits of the amplifier and synchro capacitors on the inputs to the control transformers. Any unit which has been installed will be set up as necessary for its service, but you may note that there will be almost no recognizable difference between 60- and 400-Hz units.

Because of different manufacturers and the requirements of different applications you will find a variety of synchro signal amplifiers in the fleet. These may be more simple or more complex than the unit just discussed. Several different ways of damping oscillations through the amplifier will be used, and some units may incorporate cooling fans. All of them will incorporate the basic concept of applying the input synchro signal through a control transformer, amplifying it, and using a servo motor to drive a gear train that simultaneously drives the control transformer to null the error signal, and positions the output synchro units.

ALARM SWITCH

An alarm switch is provided on the front panel of the synchro signal amplifier. This switch is the only control that needs to be touched during normal operation of the amplifier. The effect of the alarm switch and associated relay circuits is to energize an external alarm when any one of the following three conditions is present:

- Input and output synchros and excited and the alarm switch is off.
- The alarm switch is on and one or more of the input or output synchros are not excited.
- The servo unit fails to follow, within 2.5°, the input signal.

MAINTENANCE

Alarm circuits should be checked monthly. As a general rule in checking them, you energize the equipment that supplies voltage to the compass and turn on the alarm system. Then you displace the test knob, where provided, noting whether the deenergized relay causes its alarm to function. Next, deenergize each output supply circuit one at a time; the alarm should sound each time.

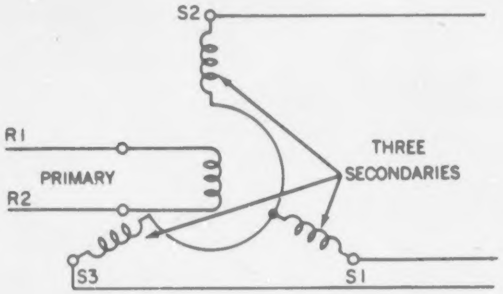
All gearing is inspected annually. Turn the gears by hand with the equipment deenergized. If dirt is found, clean the gears; if they show too much wear, replace them. Put a light coating of instrument grease on the gears.

A yearly accuracy check is required which concerns the performance of individual amplifiers. In this check, you compare the readings at the input with those at the output repeater. The readings should not vary by more than 0.1°. Check the alignment of individual units, following instructions in the manufacturer's manual. Remember that these instructions always supersede general instructions found elsewhere.

ELECTRICAL ZERO

Each type of synchro has a combination of rotor position and stator voltages which is called its electrical zero. The electrical zero condition is the reference point for the alignment of the synchro.

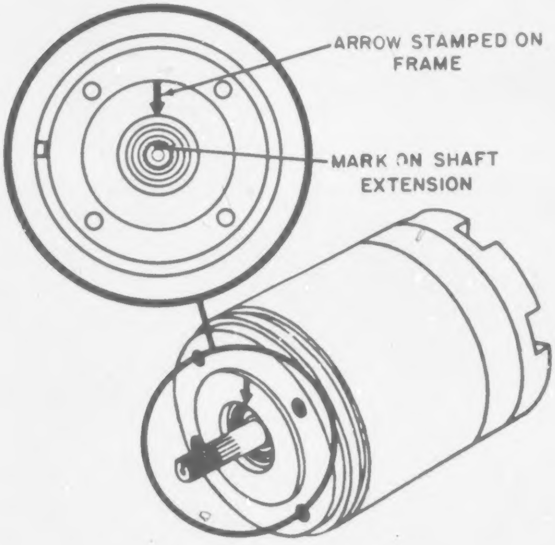
Electrical zero is the condition in which the axis of the rotor is lined up with the axis of the S2 winding (fig. 13-18A).



175.6
Figure 13-18A.—Conventional synchro unit.

In both the 0° position and the 180° position, the terminal voltage between S1 and S3 is zero. However, in the 0° position the voltages from S2 to S3 or from S2 to S1 are IN PHASE with the voltage from R1 to R2, while in the 180° rotor position the voltage from S2 to S3 (or S1) is 180° out of phase with the rotor voltage.

The electrical zero position is therefore completely defined as the position of the rotor in which the voltage between S1 and S3 is zero, and the voltage from S2 to S3 is in phase with the voltage from R1 to R2.



175.18
Figure 13-18B.—Coarse electrical zero markings.

A synchro transmitter (CX or TX) is properly zeroed if electrical zero voltages exist when the unit whose position the CX or TX transmits is set to its mechanical reference position. A synchro receiver (TR) is properly zeroed if, when electrical zero voltages exist, the device actuated by the receiver assumes its mechanical reference position. In a receiver or other unit having a rotatable stator, the zero position is the same, with the added provision that the unit to which the stator is geared is set to its reference position. The terminal-to-terminal voltages for 115- and 26-volt synchros at electrical zero are as follows:

115-VOLT SYNCHROS	26-VOLT SYNCHROS
R1 to R2 115 volts	R1 to R2 26 volts
S2 to S1 78 volts	S2 to S1 10.2 volts
S2 to S3 78 volts	S2 to S3 10.2 volts
S1 to S3 zero volts	S1 to S3 zero volts

A differential synchro unit is zeroed if the unit can be inserted into a system without introducing a change in the system. In the electrical zero position the axes of coils R2 and S2 are at zero displacement. Terminal voltages for differential units are as follows.

115-VOLT SYNCHROS	26-VOLT SYNCHROS
R1 to R3 zero volts	R1 to R3 zero volts
S1 to S3 zero volts	S1 to S3 zero volts
R3 to R2 78 volts	R3 to R2 10.2 volts
S3 to S2 78 volts	S3 to S2 10.2 volts
R2 to R1 78 volts	R2 to R1 10.2 volts
S2 to S1 78 volts	S2 to S1 10.2 volts

A synchro control transformer (CT) is properly zeroed if its rotor voltage is minimum when electrical zero voltages are applied to its stator, and turning the CT's slightly counterclockwise produces a voltage between R1 and R2 which is in phase with the voltage between R1 and R2 of the CX or TX supplying excitation to the CT stator. Electrical zero voltages for the stator only are the same as for transmitters and receivers.

ZEROING METHODS

There are various methods for zeroing synchros. The procedure used depends upon the facilities and tools available and how the synchros are connected in the system. Also, the procedure for zeroing a unit whose rotor or stator is not free to turn may differ from the procedure for zeroing a similar unit whose rotor or stator is free to turn.

Voltmeter Method

The most accurate method of zeroing a synchro is the a-c voltmeter method. The procedure and the test-circuit configuration for this method vary somewhat, depending upon which type of synchro is to be zeroed. Transmitters and receivers, differentials, and control transformers each require different test-circuit configurations.

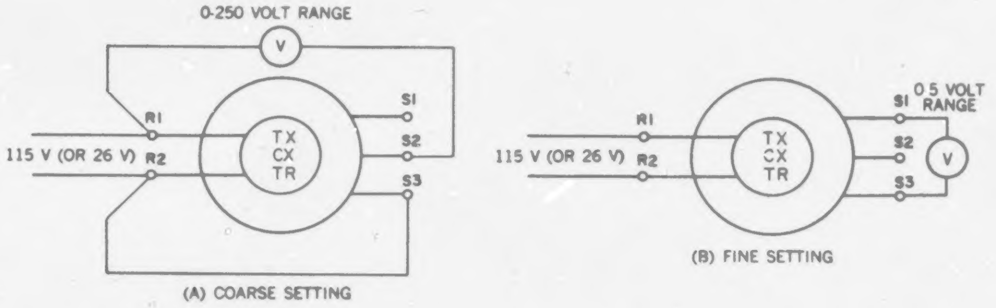
An electronic or precision voltmeter having a 0- to 250-volt and a 0- to 5-volt range should be used. On the low scale the meter should be able to measure voltages as low as 0.1 volt.

There are two major steps in the zeroing procedure of a synchro. First, the coarse or approximate setting is determined, and, second, the fine setting is made. The coarse adjustment is a check between the correct setting and a setting 180° out. Recall from the discussion of electrical zero that the difference between the two positions determines the phase relation between the voltages on S2 to S1 (or S3) and on R1 and R2. The voltages are in phase when the rotor is at its electrical zero position, and 180° out of phase when the rotor position is 180° away from electrical zero. Hence the coarse check provides a means to determine the phase relation between the supply voltage and the induced voltages in the S2 and S1 stator windings.

Standard synchros have an arrow stamped on the stator frame and a reference line scribed on the rotor shaft, as shown in figure 13-18B. With the synchro input on zero or the reference value, the alignment of the arrow and the line on the rotor will set the synchro on approximate zero. Thus, with standard synchros, this is the coarse check.

ZEROING TRANSMITTERS AND RECEIVERS.—Control transmitters, torque transmitters, and receivers are functionally and physically similar. Therefore, they are zeroed in the same manner. The zeroing procedure is broken down into steps as follows.

1. Carefully set the quantity whose position the synchro transmits to its zero or mechanical reference position.
2. Deenergize the synchro circuit and disconnect the stator leads. Set the voltmeter to its 0- to 250-volt scale and connect it into the synchro circuit as shown in figure 13-19A. Many synchro systems are energized by individual switches, therefore be sure that the synchro power is off before working on the connections.
3. Energize the synchro circuit and turn the stator or rotor until the meter reads about 37 volts (15 volts for 26-volt synchros). This is the coarse setting and places the synchro approximately on electrical zero.
4. Deenergize the synchro circuit and connect the meter as shown in figure 13-19B, using the 0- to 5-volt scale.
5. Reenergize the synchro circuit and adjust the rotor or stator for a null (minimum voltage) reading. This is the electrical zero position.

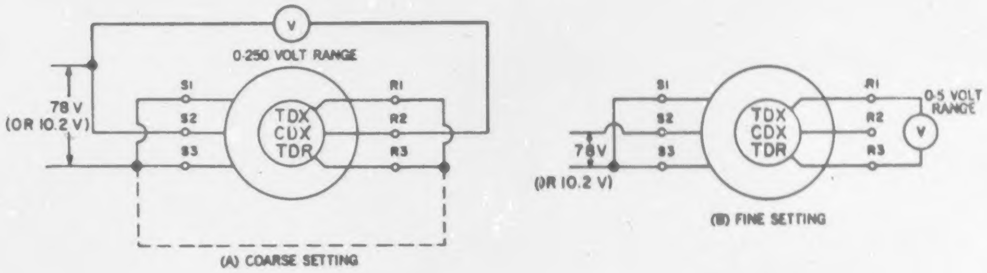


(A) COARSE SETTING

(B) FINE SETTING

53.26

Figure 13-19.—Zeroing transmitter or receiver by voltmeter method.



(A) COARSE SETTING

(B) FINE SETTING

1.121(53)A

Figure 13-20.—Zeroing differential synchros by voltmeter method.

The common electrical zero position of a TX-TR synchro system can be checked with a jumper. Put the transmitter and receiver on zero and intermittently jumper S1 and S3 at the receiver. The receiver should not move. If it does, the transmitter is not on zero and should be rechecked

ZEROING DIFFERENTIAL SYNCHROS.—To zero differential synchros by the voltmeter method proceed as follows:

1. Set the unit concerned accurately to its zero or mechanical reference position.

2. Remove all other connections from the differential leads, set the voltmeter on its 0- to 250-volt scale, and connect as shown in figure 13-20A. If a 78-volt supply is not available, 115 volts may be used. If 115 volts are used instead of 78 volts, do not leave the unit connected for more than two minutes or it may overheat.

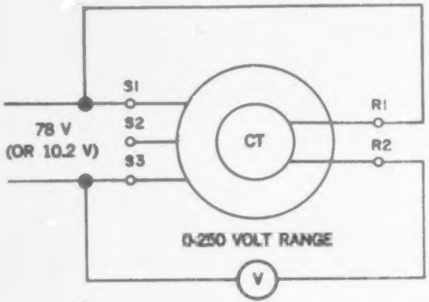
3. Unclamp the differential and turn it until the meter reads minimum. The differential is now on appropriate electrical zero. Deenergize and reconnect as shown in figure 13-20B.

4. Set the voltmeter on the 0- to 5-volt scale, and turn the differential transmitter until a null (minimum voltage) reading is obtained. Clamp the differential in this position, deenergize, and reconnect all leads for normal operation.

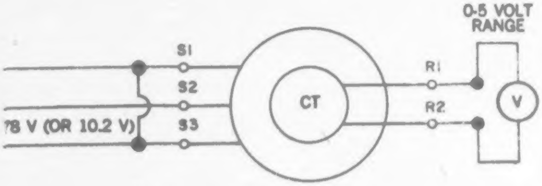
ZEROING A CT.—To zero a CT by the voltmeter method, remove the connections from the CT and reconnect as shown in figure 13-21A. Turn the rotor or stator to obtain a minimum voltage reading, then reconnect the meter as shown in figure 13-21B. Adjust the rotor or stator for a null reading, clamp the CT in position, and reconnect all leads to their original position.

Electrical Lock Method

The electrical lock method (although not as accurate as the voltmeter method) is perhaps



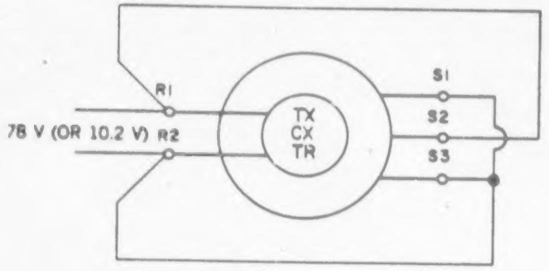
A COARSE SETTING



B FINE SETTING

53.36

Figure 13-21.—Zeroing control transformer by voltmeter method.



53.30
Figure 13-22.—Zeroing a synchro by the electrical lock method.

the fastest method of zeroing synchros. This method can only be used however, provided the rotors of the units are free to turn and the lead connections are accessible.

To zero a synchro by the electrical lock method, deenergize the unit, connect the leads, and apply power as shown in figure 13-22. The synchro rotor will then quickly snap to the electrical zero position and lock. As stated previously, 115 volts may be used as the power supply instead of 78 volts provided that the unit does not remain connected for more than two minutes.

ZEROING MULTISPEED SYNCHRO SYSTEMS

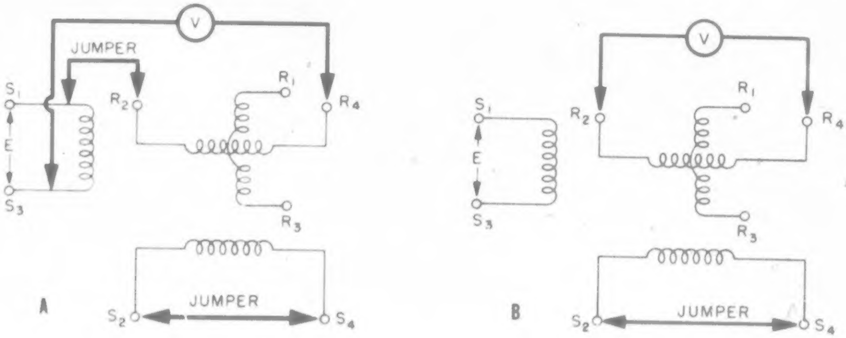
If a fine and a coarse synchro are used to define a quantity's position, the synchros must be zeroed together. As pointed out earlier, the coarse synchro will define the position of a quantity to within the range of the fine synchro's capability to define the position more precisely. From this you can reason that the coarse synchro provides the first significant figure in the numerical description of the quantity's position. Obviously then the coarse synchro is zeroed first. When zeroing the synchros in a system you can consider each synchro as an individual unit. Thus one of the methods already described can be used to zero the coarse synchro.

The next step after the coarse synchro is zeroed is to zero the fine synchro. A fine synchro provides the next significant figure in the numerical description of the quantity's position. The fine synchro is zeroed as an individual unit. But the quantity's zero or reference position has already been established with respect to the coarse synchro's electrical zero position. Hence when you zero a fine synchro the setting of the coarse synchro and the quantity must be set together.

There are a few three-speed synchro systems. These systems are zeroed in the same manner as the dual-speed systems. First, establish the zero position for the synchro which provides the most significant figure, and work down to the least significant figure. Remember that all the synchros in a system must have a common electrical zero position.

ZEROING A RESOLVER

There are many methods used to zero resolvers. Each manufacturer has his own method.



12.111
Figure 13-23.—Zeroing a resolver, (A) coarse setting, (B) fine setting.

The method described below uses the basic principles underlying all the different resolver zeroing methods.

Before a resolver can solve a problem it must have a reference position from which the input values are measured. This is the zero position of the resolver. The zero position of a resolver is determined by the angular relationship between the rotor and stator windings. Each stator winding must be perpendicular to a corresponding rotor winding. When this relationship is established, there will be no magnetic coupling between corresponding windings.

The absence of a magnetic coupling between corresponding rotor and stator windings is possible at two positions 180° apart. To ensure the correct position, so that the phase relationship between the rotor and stator is correct, the coarse zero test is made first. Figure 13-23A shows the connections for the coarse zero test. The voltage applied to the stator winding S1 - S3 is a reference voltage specified for the resolver. The two windings are connected in parallel by the voltmeter and the jumper. The voltmeter will read the applied voltage, plus or minus any voltage induced in the rotor winding. The jumper across the winding S2 - S4 is to eliminate any stray voltage that might originate from the winding.

To make the coarse zero adjustment, loosen the flange mounting screws of the stator. Looking at the rear (brush end), turn the stator counterclockwise. Stop turning when the voltmeter reads the input voltage, E. At this point you know the R2 - R4 coil has no induced voltage because the voltmeter reads the input voltage alone, meaning that the R2 - R4 is approximately at right angles to S1 - S3 and the rotor is at coarse zero.

With the voltmeter reading the E voltage, turn the stator a little beyond coarse zero. The voltage at the voltmeter should INCREASE ABOVE E, because the voltage induced in the R2 - R4 coils add to E. Be sure the voltage at the voltmeter increases to prevent zeroing at 180° out of phase.

The next step is to set the resolver on fine zero. Figure 13-23B shows you how to reconnect the jumper and voltmeter. Turn the stator so that the voltage on the voltmeter decreases, and keep shifting the meter to the lower scales until the minimum voltage reading is obtained. The minimum voltage reading means that R2 - R4 is exactly at right angles to S1 - S3, and the rotor is at fine zero. Recheck this voltage after you secure the mounting screws.

CHAPTER 14

SHIPS CONTROL ORDER AND INDICATING SYSTEMS

Current design of naval ships requires the mounting of control order and indicating units in consoles for ease of operation. Two units currently in use are the ship control console and the steering control console. On ships with automatic propulsion systems the steering control and ship control consoles are combined into one unit which contains all the necessary equipment needed for control of the ship's engineering plant. Since the circuitry in these combined units is similar to that in older shipboard consoles, you can develop an understanding of all types of units through studying the following circuits of this chapter:

(1) the engine order system, circuit MB;
(2) propeller revolution order system, circuit M;
(3) rudder angle order indicator, circuit N;
(4) rudder angle order transmitter, circuit L;
(5) steering emergency signal, circuit LB;
(6) valve position indicator, circuit VS; and
(7) burner order indicator, circuit BC.

THE SHIP'S CONTROL CONSOLE

Incorporating in a single unit the equipment required to transmit orders relative to the speed of the ship, the ship control console (fig. 14-1) is the control center for the following:

- 1MB engine order starboard circuit.
- 2MB engine order port circuit.
- Propeller revolution order system.
- Speed lights.

ENGINE ORDER SYSTEM

In addition to providing a means of transmitting desired engine direction and speed orders, the engine order system can transmit acknowledgement of these orders and relay the information to remote stations.

On combatant ships, this system usually consists of two separate circuits: 1MB starboard and 2MB port. Each circuit has a synchronous transmitter to actuate receivers and an audible signal to indicate a change in orders.

The newest systems include circuit DW (Wrong Direction Warning) which automatically signals an alarm at the throttle concerned if the throttle is placed in a direction, ahead or astern, contrary to the received order.

A block diagram of the system (fig. 14-2) shows the various units and their locations. Two transmitter-indicators are mounted in the upper section of the ship control console located in the pilothouse. Each engineroom has one indicator-transmitter (fig. 14-3A) for its associated shaft. Engine room No. 1 also has one indicator (fig. 14-3B) for the orders to the No. 2 engine. CIC, fireroom No. 1, and fireroom No. 2 each have one engine order double indicator (fig. 14-3C) which keeps CIC advised of speed changes and the firerooms alerted to changing steam requirements.

The desired speed and direction is inserted at the console by the operator and immediate indication is transmitted to both enginerooms over circuits 1MB and 2MB. Each engineroom individually acknowledges receipt of the orders. The order or order and answer is transmitted simultaneously to various stations dependent upon their equipment capabilities.

All the engine order information transits the ACO section of the main IC switchboard for damage control protection as described in chapter 4.

PROPELLER REVOLUTION ORDER SYSTEM

Circuit M transmits from the pilothouse to each propulsion gage board the ordered number of propeller revolutions per minute, and acknowledges the order from the main propulsion gage board to the transmitting station. The control

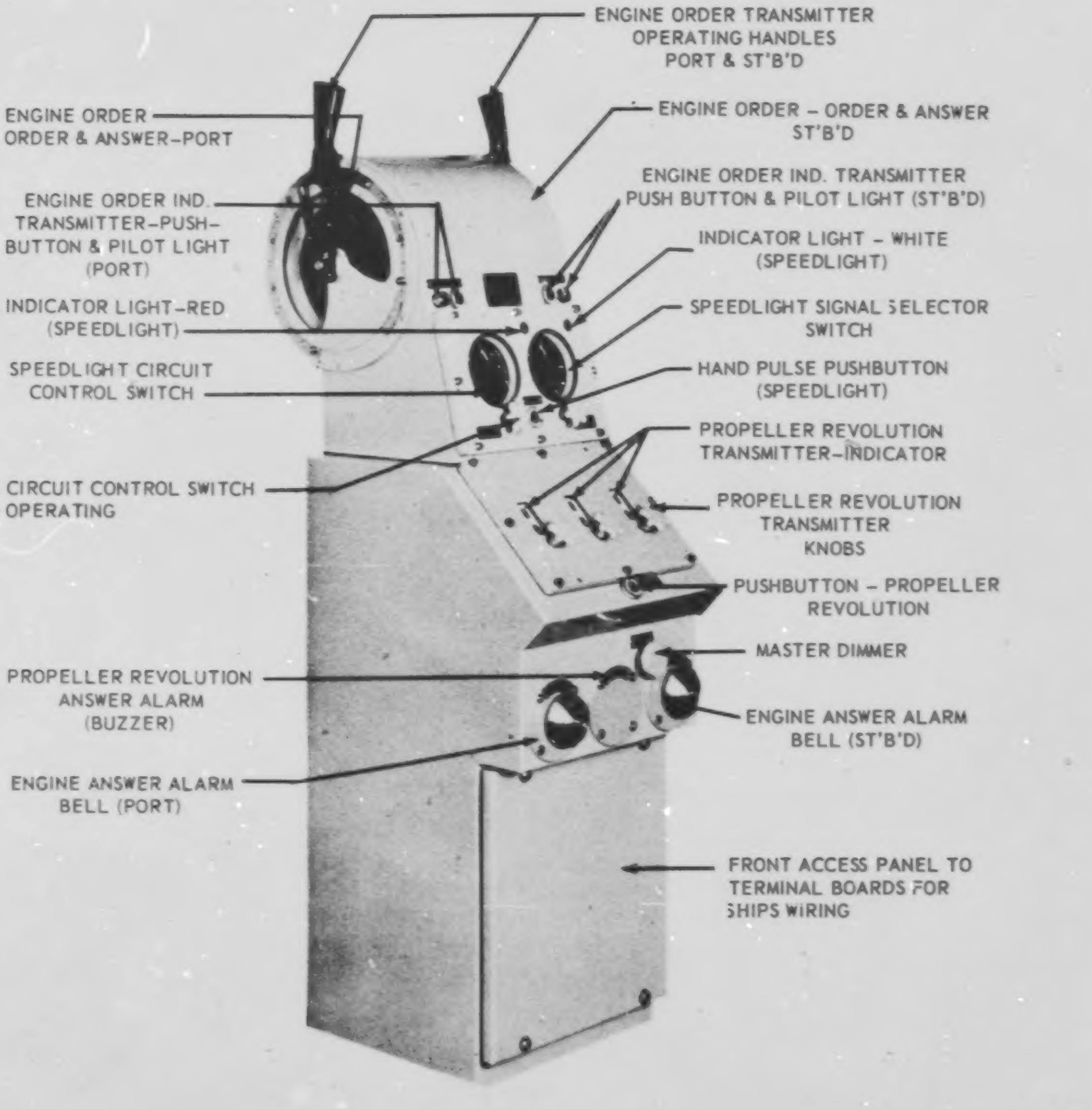
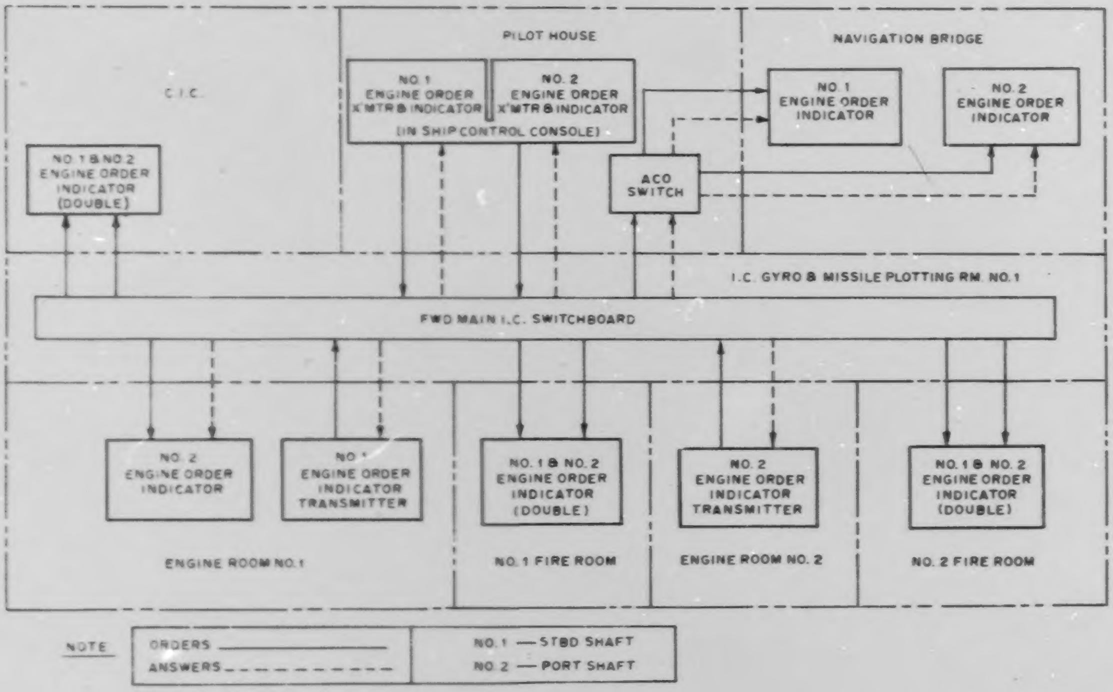

ENGINE ORDER TRANSMITTER OPERATING HANDLES PORT & ST'B'D
ENGINE ORDER ORDER & ANSWER-PORT
ENGINE ORDER - ORDER & ANSWER ST'B'D
ENGINE ORDER IND. TRANSMITTER-PUSH-BUTTON & PILOT LIGHT (PORT)
ENGINE ORDER IND. TRANSMITTER PUSH BUTTON & PILOT LIGHT (ST'B'D)
INDICATOR LIGHT - WHITE (SPEEDLIGHT)
INDICATOR LIGHT-RED (SPEEDLIGHT)
SPEEDLIGHT SIGNAL SELECTOR SWITCH
SPEEDLIGHT CIRCUIT CONTROL SWITCH
HAND PULSE PUSHBUTTON (SPEEDLIGHT)
PROPELLER REVOLUTION TRANSMITTER-INDICATOR
CIRCUIT CONTROL SWITCH OPERATING
PROPELLER REVOLUTION TRANSMITTER KNOBS
PUSHBUTTON - PROPELLER REVOLUTION
MASTER DIMMER
PROPELLER REVOLUTION ANSWER ALARM (BUZZER)
ENGINE ANSWER ALARM BELL (ST'B'D)
ENGINE ANSWER ALARM BELL (PORT)
FRONT ACCESS PANEL TO TERMINAL BOARDS FOR SHIPS WIRING
7.132

Figure 14-1.—Ship control console.

unit for this system is currently installed in the ship control console.

A propeller order indicator-transmitter (fig. 14-4A) is on the main gage board in engineroom No. 1. Like the pilothouse unit, it is self-synchronous, containing three synchro transmitters and three synchro receivers, each of which is coupled to a dial. The transmitters are further coupled to control knobs.

On the gage board of the No. 2 engineroom is a propeller order indicator (fig. 14-4B). Ordered propeller revolutions are inserted at the pilothouse unit and indicate on both gage boards. The throttleman at the No. 1 engineroom board acknowledges the received order.


PILOT HOUSE
NAVIGATION BRIDGE
C.I.C.
NO. 1 ENGINE ORDER X'MTR & INDICATOR
NO. 2 ENGINE ORDER X'MTR & INDICATOR
(IN SHIP CONTROL CONSOLE)
NO. 1 ENGINE ORDER INDICATOR
NO. 2 ENGINE ORDER INDICATOR
NO. 1 & NO. 2 ENGINE ORDER INDICATOR (DOUBLE)
ACO SWITCH
I.C. GYRO & MISSILE PLOTTING RM. NO. 1
FWD MAIN I.C. SWITCHBOARD
NO. 2 ENGINE ORDER INDICATOR
NO. 1 ENGINE ORDER INDICATOR TRANSMITTER
NO. 1 & NO. 2 ENGINE ORDER INDICATOR (DOUBLE)
NO. 2 ENGINE ORDER INDICATOR TRANSMITTER
NO. 1 & NO. 2 ENGINE ORDER INDICATOR (DOUBLE)
ENGINE ROOM NO. 1
NO. 1 FIRE ROOM
ENGINE ROOM NO. 2
NO. 2 FIRE ROOM
NOTE
ORDERS
ANSWERS
NO. 1 — STBD SHAFT
NO. 2 — PORT SHAFT

140.108

Figure 14-2. — Engine order system (circuit MB).

In the event of an engineering casualty or specific test, the engineroom can reverse the procedure by requesting specific revolutions per minute.

SPEED LIGHTS

A circuit for the regulation of the speed lights is part of the navigation lights, and is maintained by the Electrician's Mates.

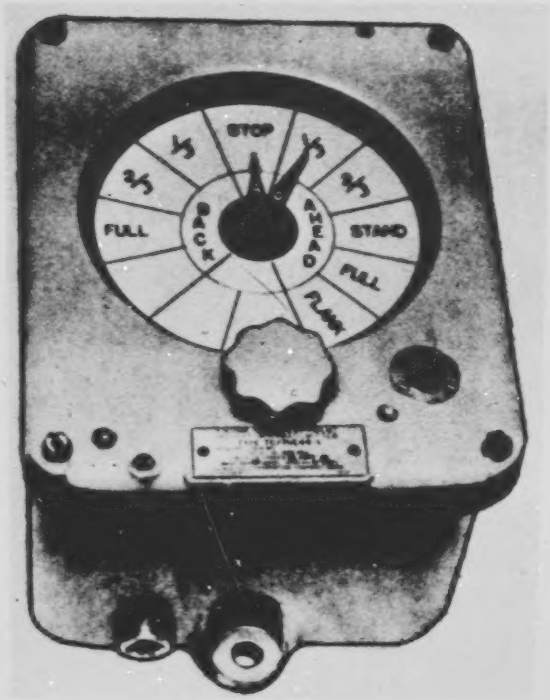
THE STEERING CONTROL CONSOLE

The steering control console incorporates the indicators and controls required to navigate the ship from the pilothouse, and to transmit steering orders to the steering gear room, when the ship is being steered from there. This console (fig. 14-5) consists of the following:

- Ships course indicator, circuit LC.
- Course to steer indicator, circuit LC.
- Combination rudder angle order indicator (circuit N) and rudder angle order transmitter (circuit L).
- Ship steering wheel (helm).
- Steering emergency signal switch, circuit LB.
- Helm angle indicator.
- It may or may not have a magnesyn compass repeater.

SHIP'S COURSE INDICATOR

The ship's course indicator is a standard synchro-driven, dual-dial gyrocompass repeater. It differs from the normal gyrocompass repeater in that it is mounted in a console and not in its own housing for bulkhead mounting.



7.126.2
Figure 14-3A.—Indicator-transmitter (circuit MB).

7.126.3
Figure 14-3B.—Indicator (circuit MB).

COURSE TO STEER INDICATOR

This indicator is a normal dual-dial repeater. It differs mainly from the ship's course indicator in that its dials are positioned from a synchro transmitter located in sonar, CIC, or other weapons control station. This repeater enables sonar, CIC, or other station to transmit a course for the helmsman to steer without having to use a means of voice transmission. The helmsman has only to match his course with the course indicated on this repeater.

RUDDER ANGLE ORDER INDICATOR

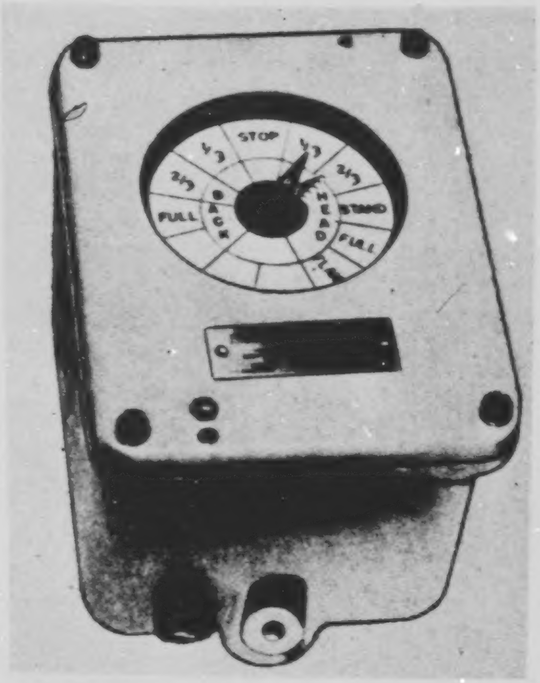
Circuit N provides a means of electrically transmitting the angular position of the ship's rudder at the rudder head to designated stations throughout the ship.

The transmitter (fig. 14-6) is located at the rudder head and consists of a synchronous transmitter mechanically linked to the rudder stock in such a manner that its shaft follows the movement of the rudder. It transmits rudder angle data to the ACO section of the steering gear room IC switchboard and from there to various ship's indicators.

The indicators consist of a fixed dial and pointer, which is mounted on the shaft of a synchro receiver. The receiver rotates the pointer to the transmitted angular displacement on the dial face.

Figure 14-7 is a block diagram of the rudder angle order system, showing the various units and their locations.

The combination rudder angle indicator-rudder order transmitter is mounted in the steering control console. A combination rudder angle indicator-rudder order indicator (fig. 14-8A) is located in the steering gear room.



7.126.4
Figure 14-3C.—Double indicator (circuit MB).

Single rudder angle indicators (fig. 14-8B) are found in the enginerooms, bridge wings, CIC, and pilothouse as well as on top of the pilothouse.

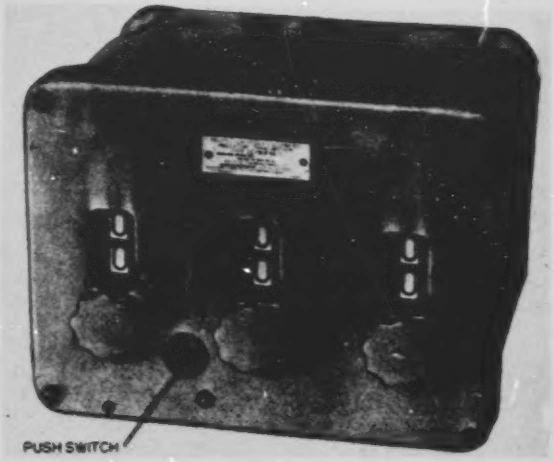
RUDDER ANGLE ORDER TRANSMITTER

Circuit L provides a means of electrically transmitting rudder angle orders from the steering control console to the steering gear room when the ship is being steered from there.

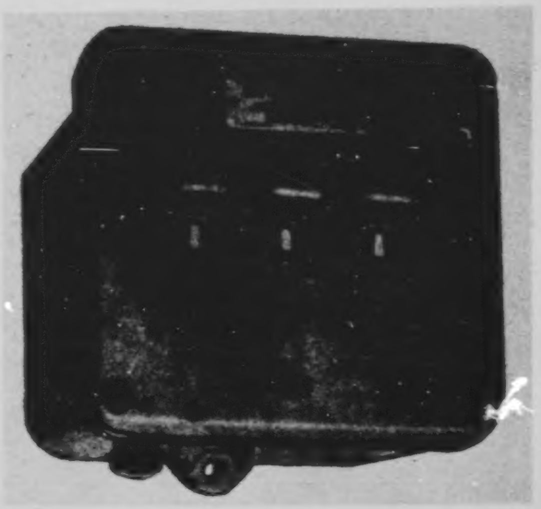
The transmitter for this circuit is located in the steering control console.

The indicator combined with a circuit N indicator (fig. 14-8A) is located in front of the steering gear room trick wheel.

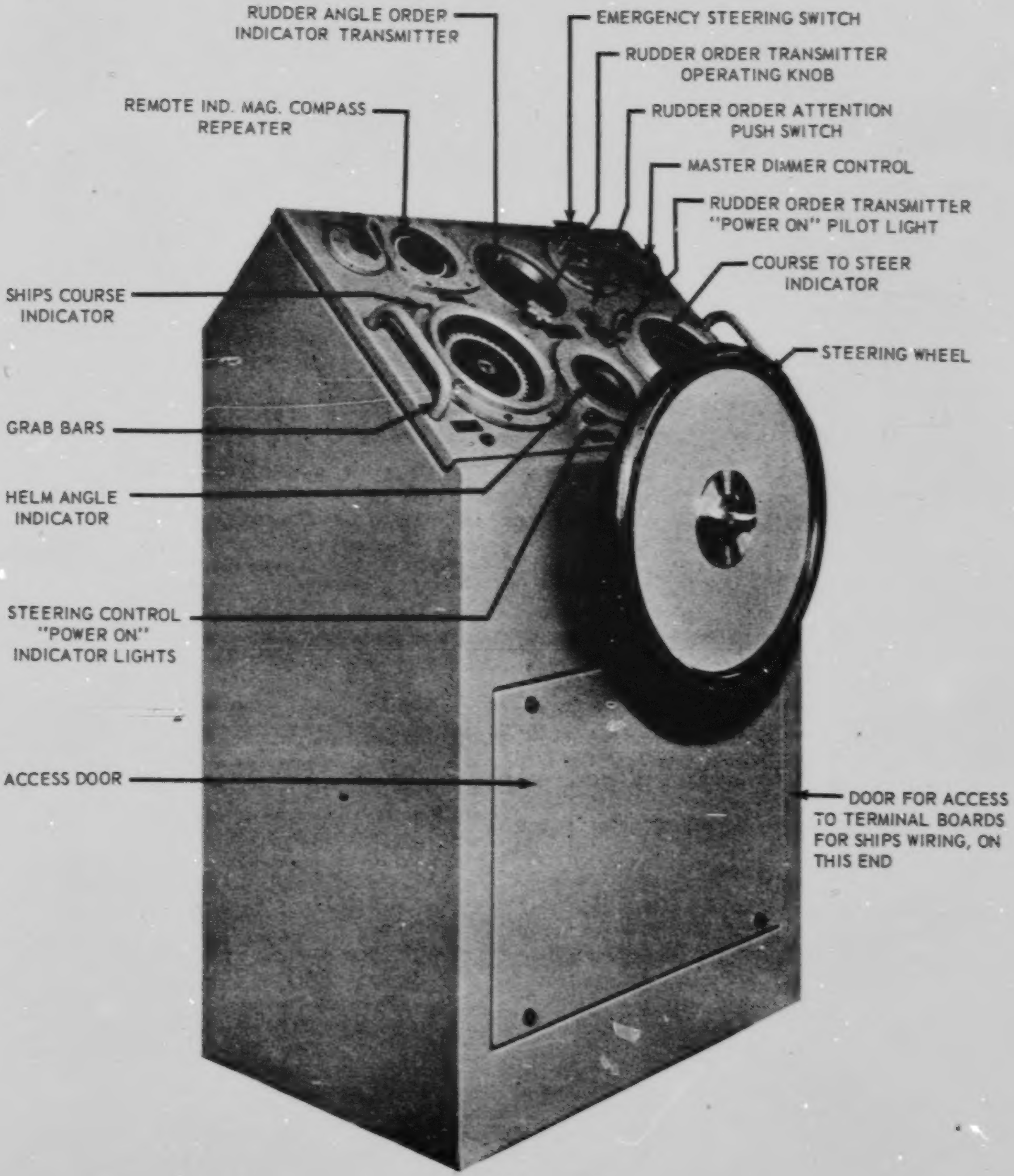
The rudder angle order transmitter is a synchronous transmitter, the shaft of which



7.122.1
Figure 14-4A.—Propeller order indicator-transmitter (circuit M).

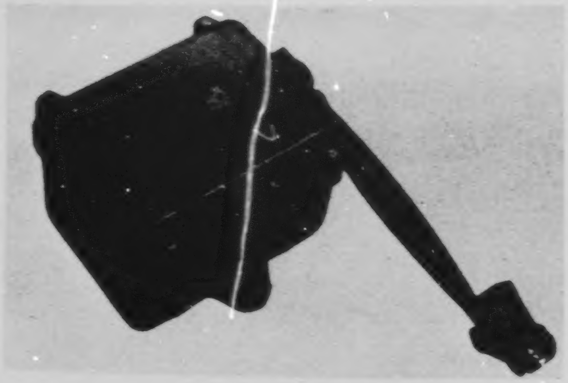


7.122.2
Figure 14-4B.—Propeller order indicator (circuit M).


RUDDER ANGLE ORDER INDICATOR TRANSMITTER
EMERGENCY STEERING SWITCH
RUDDER ORDER TRANSMITTER OPERATING KNOB
REMOTE IND. MAG. COMPASS REPEATER
RUDDER ORDER ATTENTION PUSH SWITCH
MASTER DIMMER CONTROL
RUDDER ORDER TRANSMITTER "POWER ON" PILOT LIGHT
SHIPS COURSE INDICATOR
COURSE TO STEER INDICATOR
STEERING WHEEL
GRAB BARS
HELM ANGLE INDICATOR
STEERING CONTROL "POWER ON" INDICATOR LIGHTS
ACCESS DOOR
DOOR FOR ACCESS TO TERMINAL BOARDS FOR SHIPS WIRING, ON THIS END

7.133

Figure 14-5.—Steering control console.



7.129

Figure 14-6. —Rudder angle transmitter.

is geared to a pointer and a control knob. When operated, the transmitter sends the desired rudder angle in degrees left or right to the receiver in the steering gear room.

At the indicator in the steering gear room the operater receives the ordered helm angle, then positions the trick wheel to cause the rudder angle indicator (circuit N) to match the order.

A pushbutton is provided on the console to ring a bell in the steering gear room in order that the emergency helmsman can anticipate an angle order change.

STEERING EMERGENCY SIGNAL CIRCUIT

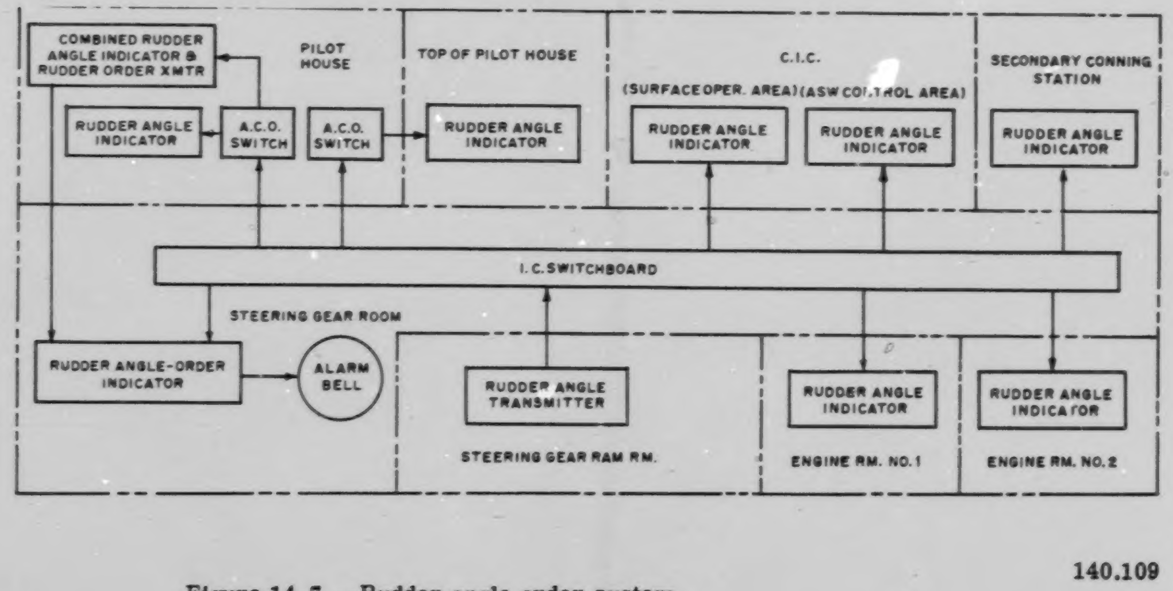
Circuit LB provides a means by which the pilothouse can warn the after steering station that a steering emergency has occurred and that steering must be controlled from there. This circuit consists of a spring return lever switch (chapter 3) located on the steering control console, and a siren (chapter 7) located in the steering gear room.

HELM ANGLE INDICATOR

The Helm Angle Indicator is a synchro receiver which is connected to a synchro transmitter attached to the steering gear. It therefore indicates the position of the steering gear or "helm angle" at all times.

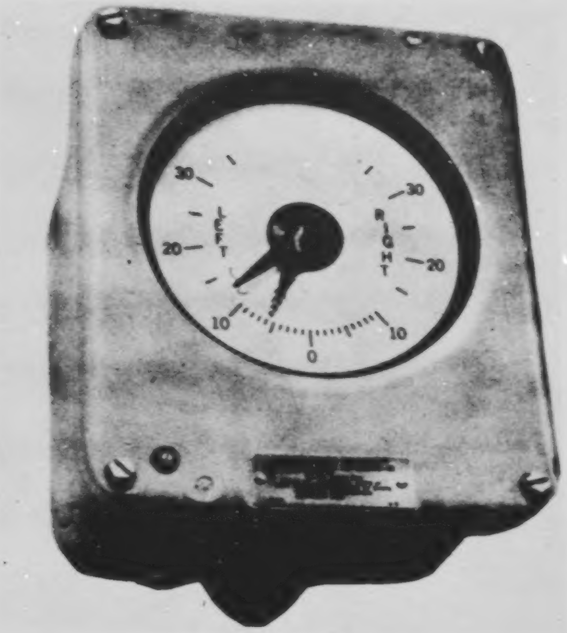
VALVE POSITION INDICATOR AND BURNER ORDER INDICATOR SYSTEMS

The valve position indicator (circuit VS) and burner order indicator (circuit BC) inform personnel at remote stations of the positions of

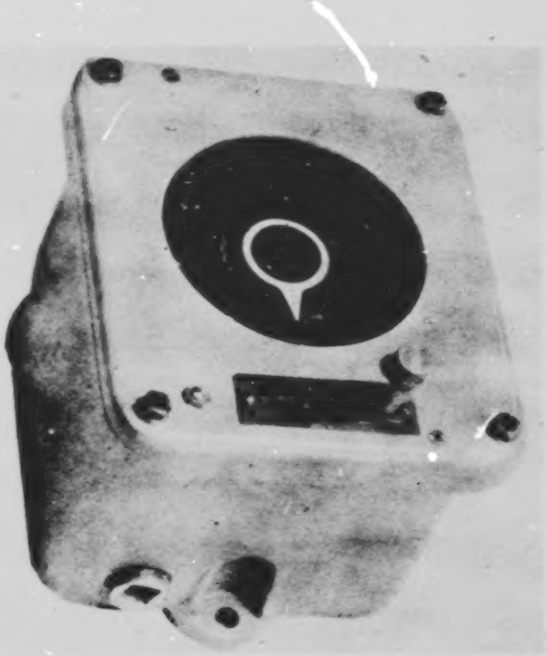

COMBINED RUDDER ANGLE INDICATOR & RUDDER ORDER XMTR
PILOT HOUSE
TOP OF PILOT HOUSE
C.I.C.
(SURFACE OPER. AREA)
(ASW CONTROL AREA)
SECONDARY CONNING STATION
RUDDER ANGLE INDICATOR
A.C.O. SWITCH
A.C.O. SWITCH
RUDDER ANGLE INDICATOR
RUDDER ANGLE INDICATOR
RUDDER ANGLE INDICATOR
RUDDER ANGLE INDICATOR
I. C. SWITCHBOARD
STEERING GEAR ROOM
RUDDER ANGLE-ORDER INDICATOR
ALARM BELL
RUDDER ANGLE TRANSMITTER
STEERING GEAR RAM RM.
RUDDER ANGLE INDICATOR
ENGINE RM. NO. 1
RUDDER ANGLE INDICATOR
ENGINE RM. NO. 2

140.109

Figure 14-7. —Rudder angle order system.



7.126.5
Figure 14-8A.—Rudder angle order indicator (circuit L & N).

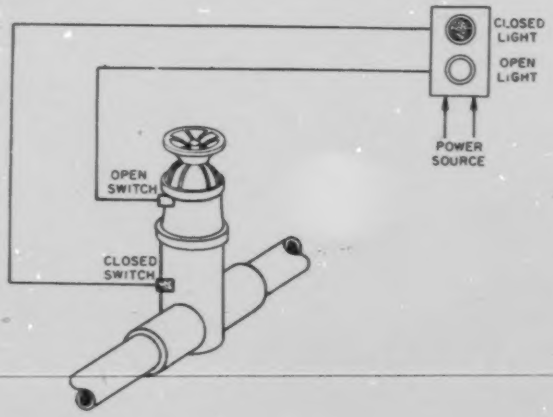


7.126.6
Figure 14-8B.—Rudder angle indicator (circuit N).

certain valves. Sensitive switches, mounted on the valve housing and actuated by the valve, energize the indicators. On most installations you will find two switches, one indicates that the valve is open and the other that the valve is closed. They normally have a "make" contact arrangement. Figure 14-9 shows a typical VS circuit arrangement. There are usually two lamps in each indicator; one lamp for the open position of a valve and the other for the closed position. The remote indicators may be found singly but are normally grouped into VS boards of from 5 to 15 indicators to indicate the positions of valves located in the same engineering space.

MAINTENANCE

If the ship control order and indicating equipment does not function properly and the cause is not immediately apparent, check for failure of the power supply, blown fuses, burned-out dial illumination, and defective



140.157
Figure 14-9.—Valve position indicator.

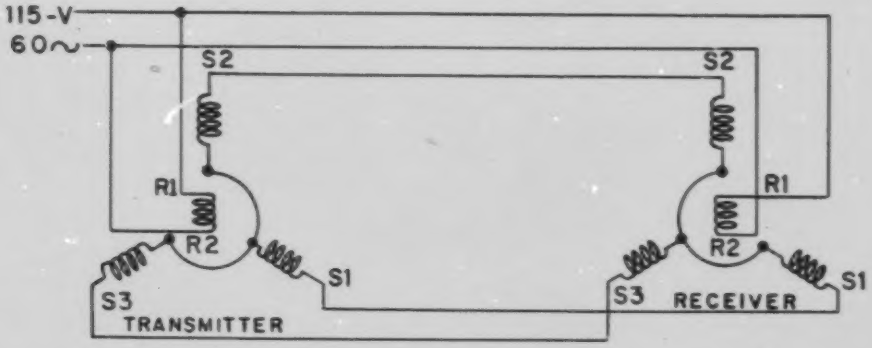
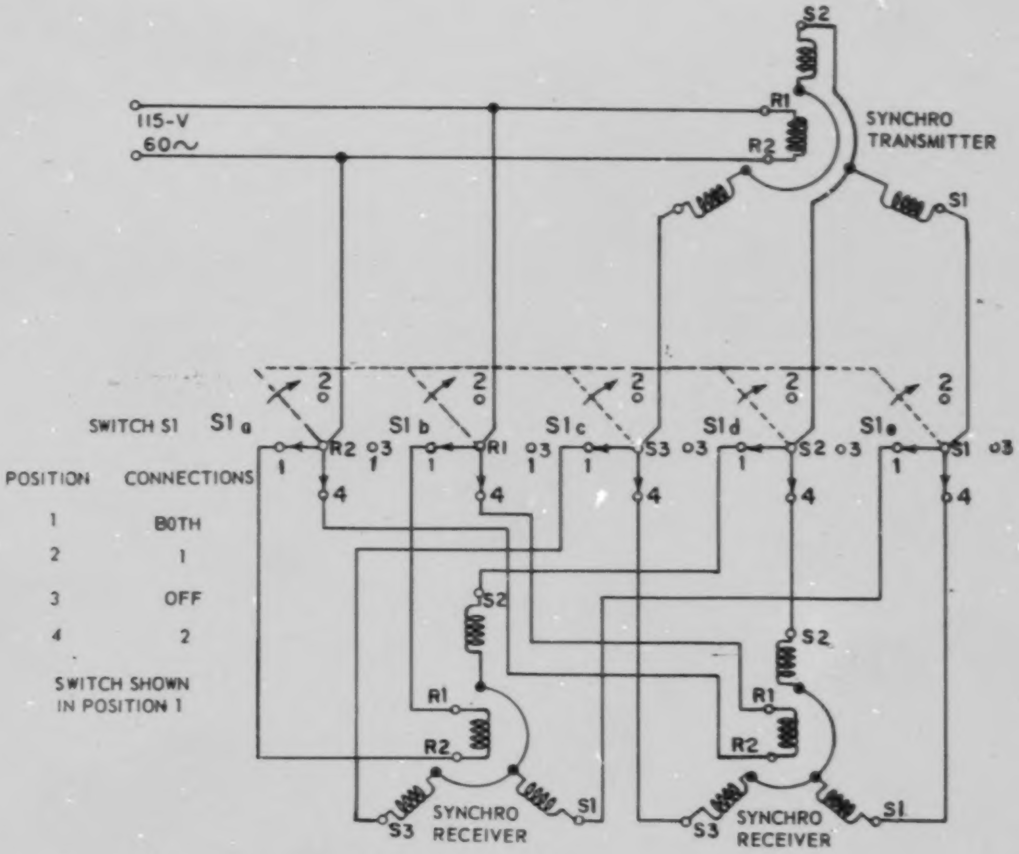

115-V
60~
S2
S2
R1
R2
S1
S3
TRANSMITTER
R1
R2
S3
RECEIVER
S1

Figure 14-10.—Simple synchro transmission system. 7.134


S2
R1
R2
SYNCHRO
TRANSMITTER
S1
115-V
60~
SWITCH S1
S1 a
S1 b
S1 c
S1 d
S1 e
R2
R1
S3
S2
S1
1
2
3
4
POSITION
CONNECTIONS
1 BOTH
2 1
3 OFF
4 2
SWITCH SHOWN
IN POSITION 1
S2
R1
R2
S3
S1
SYNCHRO
RECEIVER
S2
R1
R2
S3
S1
SYNCHRO
RECEIVER

7.135

Figure 14-11.—Connections of synchro transmitter and two independent synchro receivers through a rotary switch.

wiring, before starting a detailed examination of the circuit units and parts of the equipment. Some faults such as burned-out lamps, rheostats, shorted transformers, or wiring can often be located by sight or smell. Check for smoke or odor of burned or overheated parts.

Troubleshooting of electrical circuits and components is readily accomplished by following standard procedures for circuit tracing to isolate the fault. Do not attempt to disassemble the unit until all signal and power sources have been checked and the trouble has been definitely located on the unit. The ship control order and indicating systems operate on a standard synchro transmission system. Detailed information concerning the operation and maintenance of synchros is contained in the manufacturer's technical manual furnished with the equipment, Basic Electricity, NAVPERS 10086-B, or Synchro Servo and Gyro Fundamentals, NAVPERS 10105.

STANDARD SYNCRHO CONNECTIONS

Standard connections for synchros have been established to avoid confusion when many synchros are installed in a system. The conventional connection is for counterclockwise rotation for an increasing reading.

The standard connections of a simple synchro transmission system consisting of a synchro transmitter and receiver are illustrated in figure 14-10. The R1 transmitter and receiver leads are connected to one side of the 115-volt a-c supply line, and the R2 transmitter and receiver leads are connected to the other side of the line. The stator leads of both the transmitter and receiver are connected lead for lead—that is, S1 is connected to S1, S2 to S2, and S3 to S3. Thus, when an increasing reading is sent over the transmission system, the rotor of the synchro receiver will turn in a counterclockwise direction.

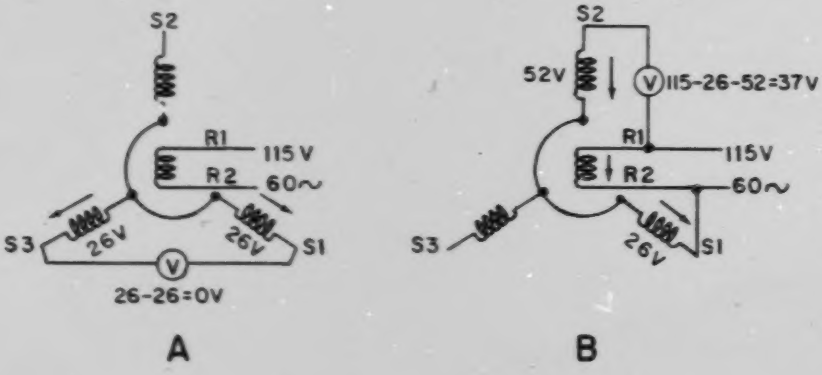
When it is desired that the shaft of the synchro receiver turn clockwise for an increasing reading, the R1 and R2 transmitter and receiver leads are connected as before, and the S1 transmitter lead is connected to the S3 receiver lead, the S2 transmitter lead to the S2 receiver lead, and the S3 transmitter lead to the S1 receiver lead.

The standard connections of a synchro transmitter to two independent synchro receivers through a rotary switch is illustrated by the wiring diagram in figure 14-11.

SETTING SYNCHROS

If a synchro system is to operate with any degree of accuracy, its synchros must be in a position of electrical zero. The methods of zeroing synchros involve the use of a voltmeter, neon lamps, two lamps and a headset, and other synchros in the system. However, the most accurate method of setting both synchro transmitters and receivers involves the use of a voltmeter as illustrated in figure 14-12.

At electrical zero, the voltage between the S1 and S3 leads must be zero and the rotor and stator voltages are subtractive between



7.136

Figure 14-12.—Zeroing synchros.

R1 and S2 when R2 and S1 are connected together. Connect a voltmeter across the S1 and S3 leads (fig. 14-12A) and rotate the energized rotor until a zero reading is obtained. However, there are two rotor positions 180° apart where a zero reading will be obtained on the voltmeter. To locate the proper zero position, it is necessary to determine that the rotor and stator voltages are subtractive. To do so, connect a jumper from S1 to the R2 leads and a voltmeter across the S2 and R1 leads (fig. 14-12B). When the polarity relationship is correct, the voltmeter will read 37v (115v - 78v = 37v). If the voltmeter reading is GREATER (115v + 78v = 193v) than the line voltage, then the rotor must be rotated 180 degrees. When the proper polarity relationship has been ascertained, connect the circuit again as in figure 14-12A, and readjust the rotor for a zero voltage reading across leads S1 and S3.

If for any reason, you must apply an external voltage to the stator windings for any length of time, use a means of obtaining a maximum of 78 volts, such as a transformer, autotransformer, variac, or dropping resistor.

CHAPTER 15

SHIP'S METERING AND INDICATING SYSTEMS

In order to properly operate a modern naval vessel, a vast amount of information must be available throughout the ship in spaces far remote from the area in which the information is originated. This information must be made available on a continuing basis with a high degree of accuracy.

The complexity of modern warfare requires that many different weapons systems control stations have available ship's speed and wind direction. Good piloting demands that the officer of the deck have shaft speed available at all times. The circuits which measure and transmit much of this information are designated IC circuits.

In measuring speeds of rotation, it is often necessary to use an indirect method, such as the one that enables a tachometer to measure the speed in rpm of an automobile engine by measuring the angle displaced by a pointer or indicator. The following IC systems apply a similar method of indirect measurement, using a friction disk and roller assembly: propeller revolution indicator system, wind direction and speed indicating system, and underwater log system.

FRICTION DISK AND ROLLER ASSEMBLY

If a disk is driven by a synchronous motor supplied with a controlled frequency, the disk will run at a constant speed irrespective of fluctuations of the ship's supply frequency. A roller placed in the center of the rotating disk does not turn.

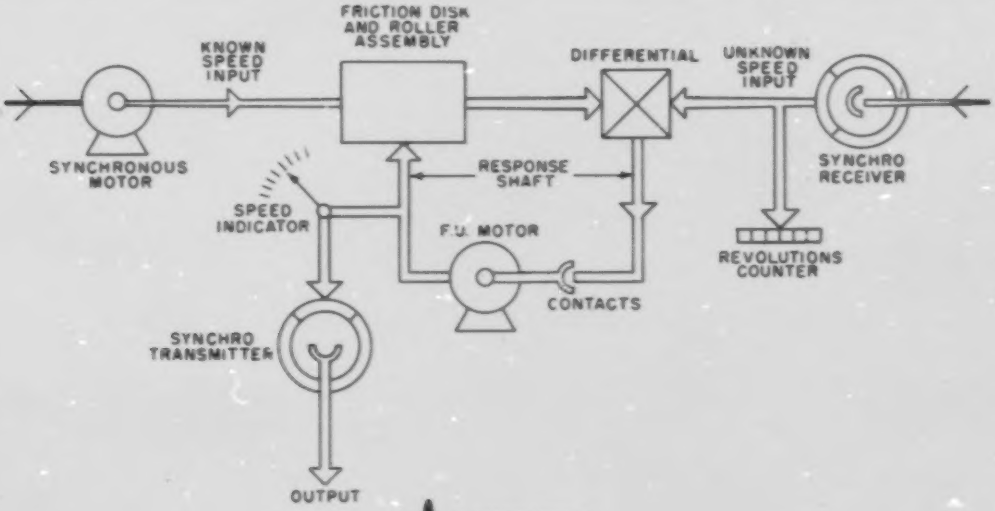
If the roller is moved out from the center of the disk, the roller turns at a speed that is proportional to the distance from the center of the disk. If the roller is moved out one-half inch from the center of the disk, the roller runs at twice the speed at which it ran when moved one-fourth inch from the center of the disk. If the position of the roller on the disk is varied, the speed of the roller is varied in direct proportion to the distance the roller is positioned from the center of the constant-speed disk.

As illustrated in figure 15-1, this device operates on the principle of comparing an unknown speed with a known speed through a differential and using the output of the differential to make these quantities approach equality. Electrical contacts operate in response to the differential output and control a followup motor that matches the two speeds (fig. 15-1A).

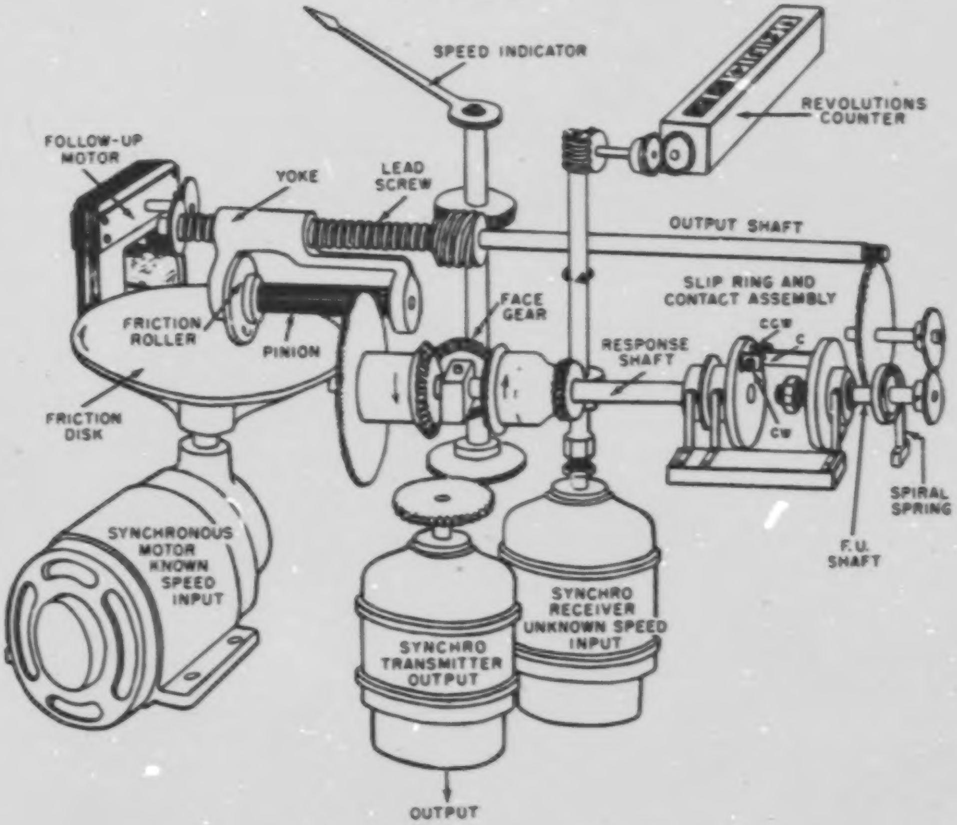
The rotation that is to be converted to an angular displacement is the unknown speed input. This input is received by the synchro receiver, which is geared to the right face gear of the differential and is free to turn about the differential (response) shaft. An extension of the synchro rotor shaft drives the six-place odometer (fig. 15-1B).

The synchronous motor is energized from the 60-hertz bus. This motor drives the friction disk at a constant speed and is the known speed input. The friction roller drives the pinion and the left face gear of the differential through a spur gear. This assembly is also free to turn about the differential (response) shaft. Hence, the left face gear rotates at a speed proportional to the distance between the position of the roller on the disk and the center of the disk. The right and left face gears of the differential rotate in opposite directions.

The slipring and contact assembly is secured to the differential (response) shaft. This assembly carries two outside contacts, CW and CCW, each connected to a slipring. These contacts do not normally make contact with the center contact C, which is mounted on the followup shaft. Thus, the contact assembly can be turned in either direction so that one or the other of the outside contacts can make contact with the center contact. This action energizes the followup motor and determines its direction of rotation.


FRICTION DISK
AND ROLLER
ASSEMBLY
KNOWN
SPEED
INPUT
DIFFERENTIAL
UNKNOWN
SPEED
INPUT
SYNCHRONOUS
MOTOR
RESPONSE
SHAFT
SYNCHRO
RECEIVER
SPEED
INDICATOR
F.U. MOTOR
REVOLUTIONS
COUNTER
CONTACTS
SYNCHRO
TRANSMITTER
OUTPUT

A SCHEMATIC


SPEED INDICATOR
REVOLUTIONS
COUNTER
FOLLOW-UP
MOTOR
YOKE
LEAD
SCREW
OUTPUT SHAFT
SLIP RING AND
CONTACT ASSEMBLY
FACE
GEAR
FRICTION
ROLLER
PINION
RESPONSE
SHAFT
CCW
C
CW
FRICTION
DISK
SPIRAL
SPRING
F.U.
SHAFT
SYNCHRONOUS
MOTOR
KNOWN
SPEED
INPUT
SYNCHRO
RECEIVER
UNKNOWN SPEED
INPUT
SYNCHRO
TRANSMITTER
OUTPUT
OUTPUT

B PICTORIAL

Figure 15-1. — Friction disk and roller assembly.

140.59

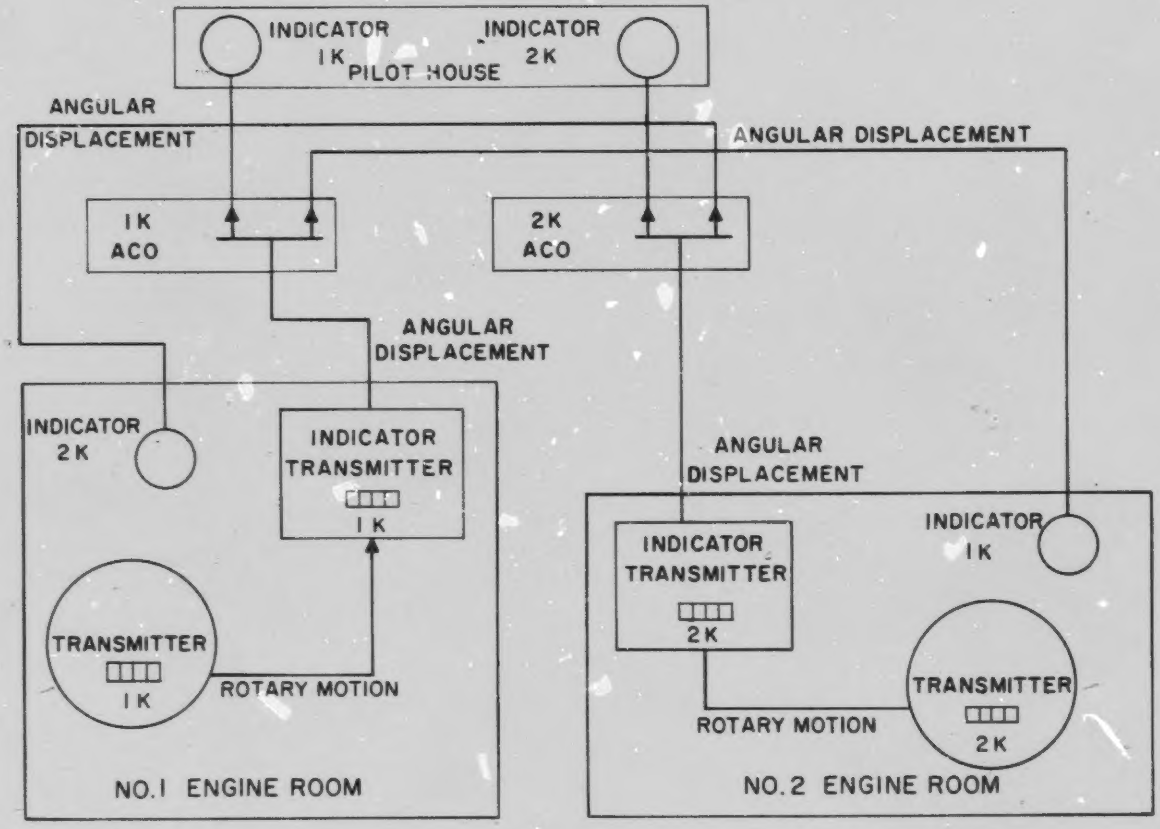
The followup motor drives the lead screw, which moves the yoke in or out (depending on the direction of rotation), thereby varying the revolutions per minute of the friction roller and the left-face gear of the differential. This action continues until the number of revolutions are the same as the right-face gear of the differential. When this equality is reached, the differential (response) shaft ceases to rotate and the contact assembly opens the circuit to the followup motor.

A pinion is cut on the end of the output shaft and engages a gear train that drives the followup shaft very slowly in the same direction as the differential (response) shaft whenever the followup motor is operating. This action restores the contacts to their normal (open) position slightly before the differential (response) shaft stops rotating to prevent hunting or overtravel of the lead screw.

PROPELLER REVOLUTION INDICATOR SYSTEM

The propeller revolution indicator system, circuit K, is used to indicate instantaneously and continuously the (1) revolutions per minute, (2) direction of rotation, and (3) total revolutions of the individual propeller shafts. The information is indicated in the enginerooms, pilot house, and other required locations.

The system comprises the (1) synchro type equipment and (2) magneto-voltmeter type equipment. The synchro type equipment is installed in large combatant ships and in many newly


INDICATOR 1K
INDICATOR 2K
PILOT HOUSE
ANGULAR DISPLACEMENT
ANGULAR DISPLACEMENT
1K ACO
2K ACO
ANGULAR DISPLACEMENT
ANGULAR DISPLACEMENT
INDICATOR 2K
INDICATOR TRANSMITTER 1K
TRANSMITTER 1K
ROTARY MOTION
NO.1 ENGINE ROOM
INDICATOR TRANSMITTER 2K
INDICATOR 1K
TRANSMITTER 2K
ROTARY MOTION
NO. 2 ENGINE ROOM

27.338

Figure 15-2.—Propeller revolution indicator system.

constructed small ships. The magneto-voltmeter type equipment is less complicated and is installed in small ships.

SYNCHRO TYPE EQUIPMENT

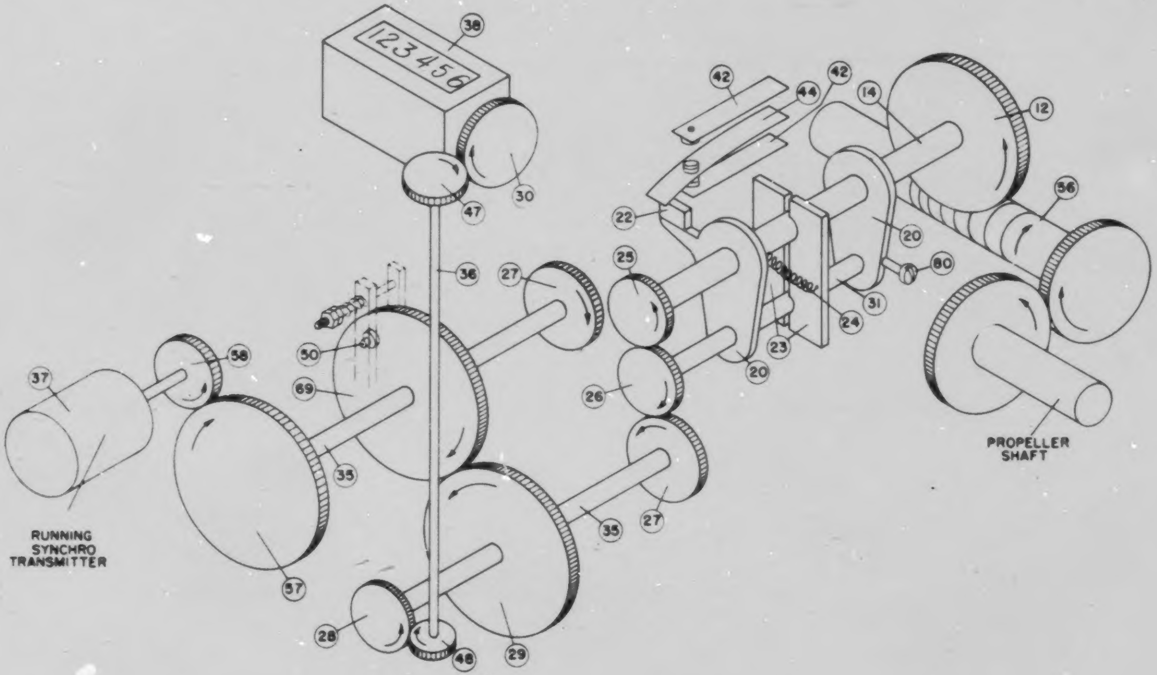
A representative synchro type propeller revolution indicator system installed in a DLG is illustrated by the block diagram in figure 15-2. The system consists of various transmitters, indicator-transmitters, and indicators. The transmitters for shafts 1 and 2 are installed on the actual propeller shaft usually near the reduction gear. The transmitters are electrically connected to indicator-transmitters in their respective throttle stations. Indicators are also installed on the gage boards in the opposite enginerooms and in the pilot houses as required by the types of ships. Each indicator is provided with a backing signal lamp which, when lighted, denotes astern rotation of the propeller shaft.

The rotary motions of the propeller shafts are transmitted by the shaft transmitters to the associated indicator-transmitters which convert the received rotary motions into stationary angular synchro displacements. The angular displacements, which are proportional to the speeds of the propeller shafts, are transmitted to indicators located at various stations. The indicators repeat the rpm readings received from the associated indicator-transmitters.

Transmitter

The transmitter, one for each propeller shaft, is used to indicate the revolutions of the propeller shaft and to transmit the speed and direction of rotation of the propeller shaft to the associated indicator-transmitter.

The unit consists of a running synchro transmitter, revolution counter, and contact assembly (fig. 15-3). These components, which are actuated by suitable gearing, are mounted in a watertight housing to form a complete transmitter subassembly. The transmitter is either gear driven from the propeller shaft, or is directly



7.139

Figure 15-3. —Gearing diagram of transmitter.

coupled to the end of a stub shaft of the propulsion machinery as required by the particular installation. The synchro transmitter is always driven at twice the propeller speed in a constant clockwise direction.

A drive worm, cut integral with the shaft 56, meshes with worm gear 12, which is secured to shaft 14. The ratio is such that shaft 14 is driven at exactly one-tenth the propeller speed. The gear 25 is attached to shaft 14 and the links 20 are free to swing on the shaft. The lower ends of links 20 support the swinging shaft 31. The gear 26 is attached to shaft 31. The friction blocks 23 are held in contact with the hubs of gears 25 and 26 by the spring 24. The friction blocks restrain the rotation of the gears 25 and 26 and swing the links assembly, including shaft 31 and gear 26 in the direction of rotation of gear 25. This action engages gear 26 with one of the two gears 27, the selection depending on the direction of rotation of gear 25. The screws 80 limit the angular swing of the links assembly.

The gears 27 and secured to the respective side shafts 35, which also carry gears 29 and 69. These gears are meshed and drive each other alternately, depending on which one of the two gears 27 is engaged with the swinging idler gear 26. Gears 29 and 69 do not reverse when the propeller shaft reverses because idler gear 26 reverses rotation each time it swings from side to side. The same is true for gears 28 and 57, because they are mounted on the hubs of gears 29 and 69, respectively. Gear 57 engages gear 58 which is mounted directly on the shaft of the synchro transmitter 37. The overall gear ratio between the transmitter shaft 56, and the shaft of the synchro transmitter is such that the synchro shaft is always driven at twice the propeller speed in a constant clockwise direction.

The revolution counter 38 which is driven at one-tenth the propeller speed, is driven through helical gears 28, 48, 47, and 30. The reading is directly in terms of propeller revolutions because each revolution of the counter shaft registers a count of ten. The brake shoes 50 prevent the synchro transmitter 37 from driving the counter 38, backward during brief periods of rapid speed reduction.

The contact assembly is actuated by a small insulating block 22, attached to one of the swinging links 20. The block moves up and down as the link swings with reversals of driving rotation. This action moves the center spring contact 44 from the bottom to the top stationary contact 42, and vice versa. The center contact and one of the stationary contacts energize the signal lights in the remote indicator when the propeller shaft rotates in the astern direction.

Indicator-Transmitter

The indicator-transmitter installed in each throttle station is used to convert the running speeds (received from the associated shaft transmitters) into angular synchro displacements which are transmitted to the various indicators.

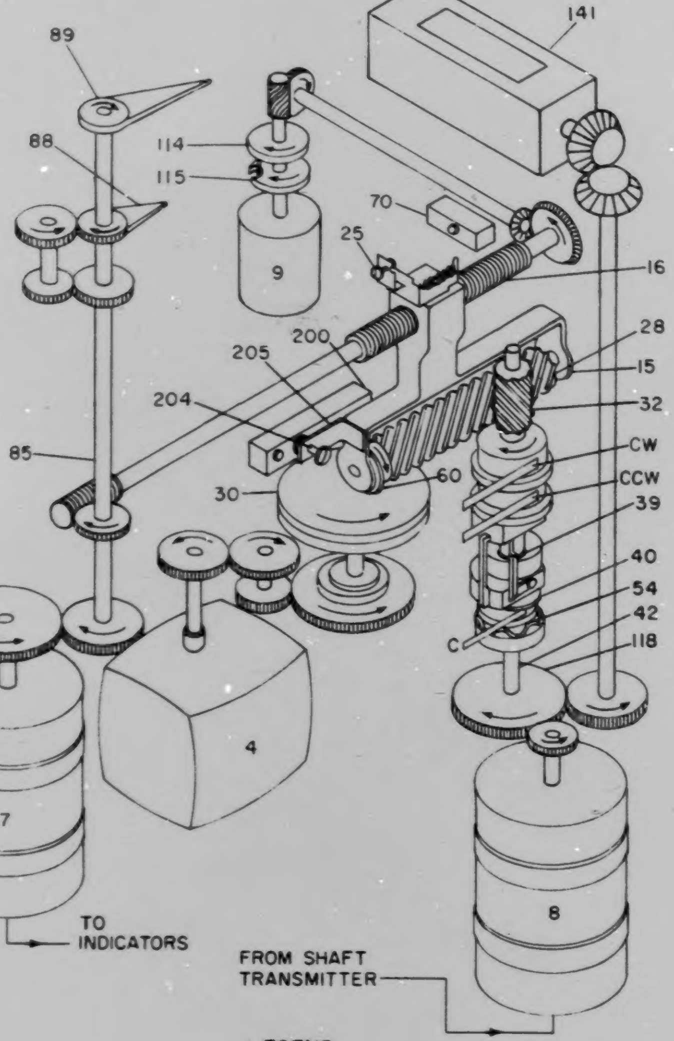
The unit (fig. 15-4) consists of a running synchro receiver, a speed-measuring mechanism, a positioning synchro transmitter, revolution counter, two pointers, a dial, and a backing signal. These components and associated gears are mounted on a baseplate to form a complete indicator-transmitter subassembly enclosed in a watertight housing.

The two concentric revolving pointers indicate on a dual-marked fixed-dial the output in rpm of the speed-measuring mechanism. The inner scale, marked for each 100 rpm only, is indexed by the short pointer 88. The outer scale, calibrated from zero to 100 rpm with numerals for each 5 rpm is indexed by the long pointer 89. The positioning synchro transmitter 7, and pointer 88 and 89 are geared to the friction roller 60, and followup motor 9. The long pointer 89 makes one complete revolution every 100 rpm and the short pointer 88 makes one complete revolution for full scale indication. The relative direction of the speed is indicated by the backing signal indicator which is lighted only when the propeller shaft rotates in the astern direction.

The running synchro receiver 8 is driven electrically by the associated shaft transmitter at a speed exactly one-tenth that of the propeller shaft. The running synchro drives the input shaft of the speed-measuring mechanism through gear 118. The speed-measuring mechanism converts the rotary motions into proportional angular displacements. The running synchro 8 also drives the revolution counter 141 through gears at a speed exactly one-tenth that of the propeller speed. The revolution counter registers the total propeller revolutions directly, irrespective of the direction of rotation.

The positioning synchro transmitter 7 receives the angular displacement from the speed-measuring mechanism and transmits these displacements to the remotely located indicators.

The speed measuring mechanism operates on the friction disk and roller assembly principle.


141
89
88
114
115
70
25
9
16
200
205
28
15
32
204
85
CW
CCW
39
30
60
40
54
42
C
118
4
7
8
TO INDICATORS
FROM SHAFT TRANSMITTER

LEGEND

4 – SYNCHRONOUS MOTOR
7 – POSITIONING SYNCHRO TRANSMITTER
8 – RUNNING SYNCHRO RECEIVER
9 – FOLLOWUP MOTOR
15 – TRAVELING YOKE
16 – LEAD SCREW
25 – SWITCH OPERATING SCREW
28 – HELICAL GEAR
30 – FRICTION DISK
32 – HELICAL GEAR
39 – SLIP RING AND CONTACT ASSEMBLY
40 – HUB ASSEMBLY
42 – INPUT SHAFT
54 – SPRING WASHER
60 – FRICTION ROLLER
70 – LIMIT SWITCH
85 – POINTER SHAFT
88 – INNER POINTER
89 – OUTER POINTER
114 – DRIVEN DISK
115 – DRIVE DISK
118 – INPUT GEAR
141 – MECHANICAL COUNTER
200 – SPEED SIGNAL SWITCH
204 – ACTUATOR SCREW
205 – BRACKET

7.140

Figure 15-4.—Gearing diagram of indicator-transmitter.

The unknown speed is the input of the running synchro receiver 8, which is geared to the input shaft 42 of the speed-measuring mechanism through gear 118.

The known speed is provided by the synchronous motor 4, which drives the friction disk 30 through gears at a constant speed. The gearing is such that the disk speed is 16 2/3 rpm for 200 range units and 33 1/3 rpm for 400 range units. The friction disk is held in continuous contact with the friction roller 60, which is integral with the helical gear 28. The friction roller and helical gear are mounted on the traveling yoke 15, which has a total longitudinal motion of approximately 1.10 inches along the radius of the friction disk 30. The yoke is positioned along the disk radius by the lead screw 16, which is driven by the followup motor 9.

The friction roller 60, integral with helical gear 28, drives the helical gear 32, which is mounted on, but free to turn through a limited range about, the input shaft 42. Thus, the helical gear rotates at a speed proportional to the distance between the position of the roller on the disk and the center of the disk. The radius of contact at any given point will determine the drive ratio and speed at which the roller 60, and gears 28 and 32 will rotate.

The speed of helical gear 32 is automatically adjusted to match the speed of the running synchro driven gear 118, by the slipring and contact assembly 39, the upper two sliprings of which are mounted on the hub of gear 32 and are free to turn through a limited range about the input shaft 42. The assembly carries two outside brush contacts CW and CCW, each of which slides on a slipring. The center brush contact C slides on a slipring which is attached to the hub 40 and is secured to the input shaft 42 by the friction thrust washer 54. The contact assembly can be turned in either direction so that one or the other of the outside contacts can mate with the center contact. This action energizes the followup motor 9 and determines its direction of rotation.

When the input gear 118 and the helical gear 32 are running at exactly the same speed, the contacts are open, the followup motor 9 is deenergized, and the indicator pointers 88 and 89 are stationary. However, if the speed of gear 118 changes, the followup motor 9 is energized and drives the lead screw 16, which moves the yoke 15, in or out, depending on the direction of rotation. If the speed of gear 118 is faster than the original balanced speed, the CW contacts close, and if the speed is lower, the CCW contacts close. The contacts will remain closed to energize the followup motor in a correcting direction until the radius of disk contact with roller 60 reaches a new value where the speed of gear 32 is again equal to that of gear 118. At this point the contacts open to deenergize the followup motor.

At zero (rpm) input from the running synchro receiver 8, gear 118, is stationary and the contacts of the slipring assembly will cause the followup motor 9 to move the lead screw 16, forging the friction roller 60, toward the center of the friction disk 30. At the exact center, the indicator pointers 88 and 89 should read zero rpm, and the positioning synchro transmitter 7 should be on electrical zero. However, the pointers will not reach the exact scale zero because a limiting switch (not shown in fig. 15-4) deenergizes the synchronous motor 4 at a pointer indicator of approximately 1 rpm.

The full scale indication should occur when the point of roller contact is exactly 1 inch from the center of the disk 30. The indicators provide for an overspeed indication of about 10 percent above full scale (1.10 inches disk radius) before the limit switch 70 is actuated.

The indicator-transmitter can be provided with speed signal switch 200 to continuously energize a remote light or other signal at propeller speeds below a specified value. The signal setting is adjustable from about one-quarter of full speed down to about 5 rpm. As the speed of the propeller shaft decreases from higher values above the switch operating point, the yoke 15, bracket 205, and actuator screw 204, are advanced along the lead screw 16, until the roller and arm of the stationary SPDT switch 200, are lifted by the actuator screw 204. The speed value at which the switch is operated is determined by the height of the actuator screw 204, above the bracket 205. The speed signal switch is adjusted by turning the actuator screw until the desired operating point is obtained. After the switch has been actuated in decreasing speed direction, it will remain actuated at lower speeds down to zero. Also, when the propeller speed increases, the OFF or release point of the switch will occur at a value slightly above the ON speed value in a decreasing direction because of the operating differential inherent in the microswitch 200.

Indicator with Revolution Counter

The indicator with revolution counter installed in the throttle stations of some ships is used to indicate the rpm and total revolutions of the associated propeller shaft. The unit consists of a positioning synchro receiver and a running synchro receiver mounted on a baseplate. A revolving pointer indicates on a dial the rpm of the associated propeller shaft.

The positioning synchro receiver is driven by the positioning synchro transmitter in the associated indicator-transmitter unit (fig. 15-4), and positions the indicator pointer through gears. The running synchro receiver is driven by the associated running synchro transmitter and drives the revolution counter through gears. The entire subassembly is enclosed in a case to form a complete indicator unit. A backing signal light in the unit is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the astern direction.

Indicator

The indicator installed in the pilot house is used to indicate the rpm of the associated propeller shaft. The unit consists of a positioning synchro recieiver and a revolving pointer that indicates on a dial the rpm of the associated propeller shaft. The synchro receiver is driven by the positioning synchro transmitter in the associated indicator-transmitter unit (fig. 15-4). The indicator is provided with a backing signal that is energized by the unidirectional mechanism in the shaft transmitter when the propeller shaft rotates in the reverse direction.

MAGNETO-VOLTMETER-TYPE EQUIPMENT

The magneto-voltmeter propeller revolution indicating equipment consists of a transmitter of the magneto type geared to each propeller shaft and electrically connected to remotely located indicators of the voltmeter type. The wiring diagram of a representative magneto-voltmeter propeller revolution indicator system is illustrated in figure 15-5. The speed of the propeller shaft is converted by the magneto into a proportional d-c voltage. The indicators receive this voltage and indicate on the associated scales the rpm of the propeller shaft. The magneto-voltmeter indicating equipment is self-energizing and does not require a separate power source for operation.

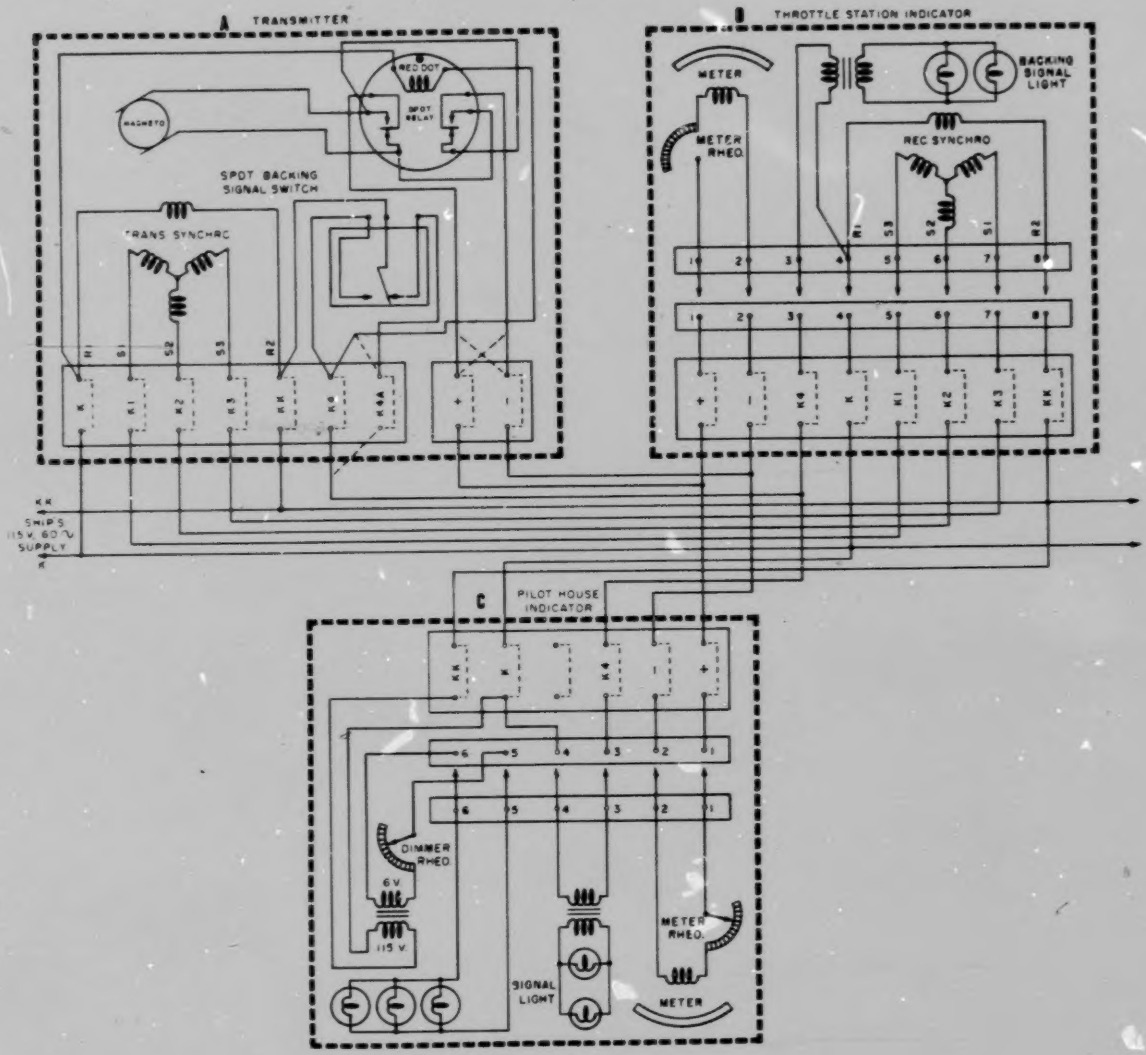
Transmitter

The magneto transmitter, coupled to the propeller shaft directly or through gears, is used to generate and transmit to the indicators speed, direction, and total number of revolutions of the propeller shaft. The unit (fig. 15-5A), consists of a magneto, synchro transmitter, revolution counter, and a unidirectional mechanism (not shown). These components are mounted on a baseplate to form a complete transmitter subassembly enclosed in a watertight housing.

The magneto is a permanent magnet type of d-c generator which is driven through two bevel gears at a speed proportional to that of the propeller shaft. At an armature speed of 1000 rpm the output of the magneto is 3 volts. The permanent magnet field is stationary, and the armature rotates. The armature winding consists of a distributed closed circuit winding which is connected to a multisegment commutator. The segments and brushes are usually gold to prevent corrosion and to maintain satisfactory conductivity. The polarity of the generated voltage changes with reversal of armature rotation. For this reason, the output of the magneto is fed through the reversing contacts of a DPDT relay to the terminals marked "+" and "-". Whenever the propeller shaft rotates in the reverse direction, the relay coil is energized by a SPDT switch which is automatically actuated by a swivel arm in the unidirectional mechanism. This action causes the relay contacts to transpose the magneto connections to the terminal strip so that the output of the transmitter retains uniform polarity irrespective of the direction in which it is driven. The SPDT switch also simultaneously energizes a backing signal in the remotely located indicators.

The revolution counter registers the total number of propeller revolutions locally at the magneto transmitter, and the synchro transmitter transmits these revolutions to the synchro receiver which drives the associated revolution counter in the remote indicator. The revolution counter and the synchro transmitter are mechanically driven at one-tenth the propeller speed through appropriate gearing by the input shaft.

The unidirectional mechanism (fig. 15-6), a gear changing device, is incorporated in the gear train that drives the revolution counter and the synchro transmitter in order to add the propeller revolutions in both the ahead and astern directions of the propeller shaft. The mechanism consists of a friction disk, two swivel-mounted idler gears, and a spring lever. The two swivel-mounted idler gears are located between the driving and driven gears so that the driven gear is alternately driven by either the

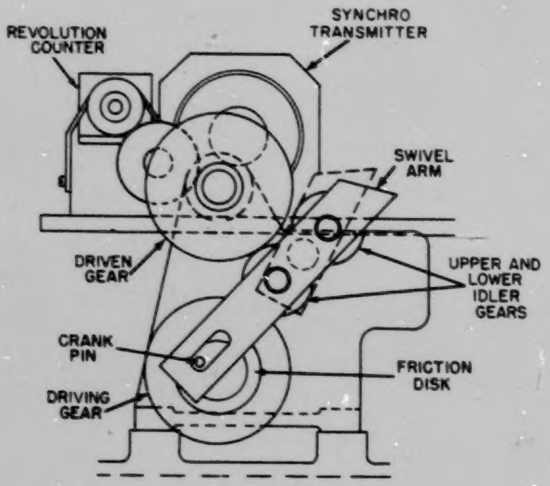

A TRANSMITTER
B THROTTLE STATION INDICATOR
MAGNETO
RED DOT
SPDT RELAY
SPDT BACKING SIGNAL SWITCH
TRANS SYNCHRO
R1
S1
S2
S3
R2
K
K1
K2
K3
KK
K4
K4A
+
-
METER
METER RHEO.
BACKING SIGNAL LIGHT
REC SYNCHRO
KR
SHIP'S 115 V. 60 ~ SUPPLY
K
C PILOT HOUSE INDICATOR
DIMMER RHEO.
6 V.
115 V.
SIGNAL LIGHT
METER RHEO.
METER

7.141

Figure 15-5. —Wiring diagram of megneto-voltmeter propeller revolution indicator system.

upper or lower idler gear, as determined by the position of the swivel arm.

The spring lever (not shown), is attached to the swivel arm, the lower end of which is slotted and engages a crank pin located off-center on the friction disk. The friction disk presses against the driving gear and rotates with it until the crank pin reaches the lower extremity of the slot in the lever where it is restrained. When the driving gear reverses direction of rotation, the disk rotates with it until the crank pin reaches the upper extremity of the slot in the lever where it is again restrained. Thus, the rotary motion of the friction disk simultaneously rocks the swivel arm causing a transposition of the upper and lower idler gears with respect to the driven gear. This action automatically drives the driven gear counterclockwise irrespective of the direction of rotation of the driving gear.



7.142

Figure 15-6. — Unidirectional mechanism.

Indicator with Revolution Counter

The indicator with revolution counter installed in the throttle station (fig. 15-5B) is used to indicate the rpm and total revolutions of the associated propeller shaft. The unit consists of a meter, synchro receiver, revolution counter, and backing signal lamp. A revolving pointer indicates on the dial the rpm of the associated propeller shaft.

The meter is essentially a d-c voltmeter calibrated in terms of propeller rpm so that an impressed terminal voltage or approximately 3600 millivolts will cause a full-scale deflection of the pointer. The meter is energized by the generated output voltage of the d-c magneto located in the shaft transmitter unit.

The revolution counter is driven through gears by the synchro receiver to indicate the total rpm of the propeller shaft. The synchro receiver is driven electrically by the synchro transmitter in the assoicated shaft magneto transmitter.

The backing signal indicator consists of a double lamp assembly provided with a 115-to 6-volt transformer and red target window. When the propeller shaft rotates in the astern direction, the unidirectional mechanism in the shaft transmitter actuates the SPDT switch to energize the lamps and illuminate the red target window.

Indicator

The indicator installed in the pilot house (fig. 15-5C) is used to indicate the rpm of the propeller shaft. It is similar in appearance and construction but smaller than the previously described unit installed in the throttle station. The unit is provided with dial illumination and a dimmer rheostat but does not include a revolution counter.

MAINTENANCE

Preventive maintenance for synchro and magneto-voltmeter types of propeller revolution indicating equipment consists of keeping the equipment clean, free running, and properly lubricated. The equipment should be deenergized during long periods of inactivity. This will cause lower internal temperatures in the instruments and reduce the tendency for the hot lubricants to drip out of the mechanisms.

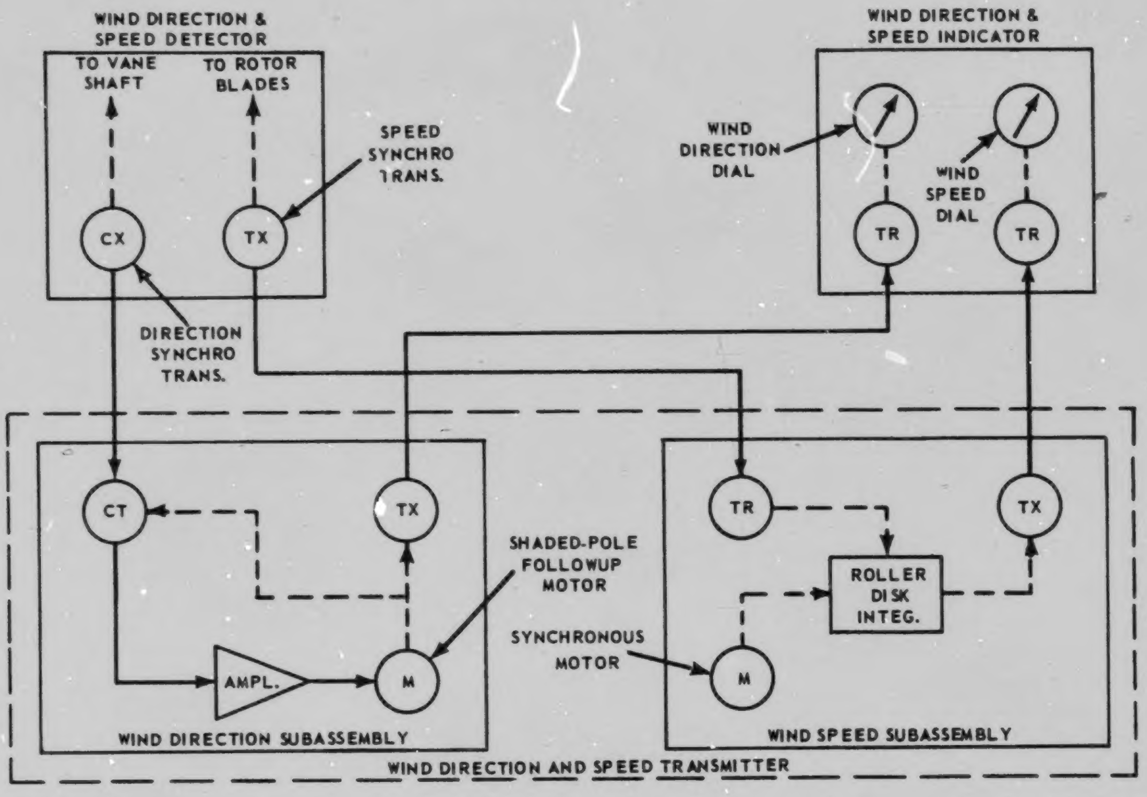
Open all synchro type transmitters and indicator-transmitters periodically, observe the condition of the gear teeth and remove any accumulation of dirt or hardened grease. Lubricate all running and worm gears according to the Planned Maintenance Subsystem Manual. The main shaft bearings are usually sealed and require no lubrication.

Keep the slipring assembly and contacts in the indicator-transmitter clean and free of any lubricant. Oil or grease on the sliprings will cause faulty operation of the followup motor. The sliprings may be cleaned with alcohol or a fine jeweler's file. Do not use sandpaper or emery cloth.

Synchro and magneto-voltmeter type indicators require no preventive maintenance other than inspections for cleanliness and freedom of motion of the moving parts. Use a wet cloth when cleaning the windows of the magneto-voltmeter type meters and let the window dry naturally. If the window is rubbed with a dry cloth, the friction may generate a static charge which will attract the instrument pointer and cause an error in the meter reading.

WIND DIRECTION AND SPEED INDICATOR SYSTEM

The wind direction and speed indicator system, circuits HD and HE, is used to indicate instantaneous and continuously the (1) wind direction in degrees relative to the ship's heading, and (2) wind speed in knots relative to the ship.


WIND DIRECTION & SPEED DETECTOR
TO VANE SHAFT
TO ROTOR BLADES
SPEED SYNCHRO TRANS.
CX
TX
DIRECTION SYNCHRO TRANS.
WIND DIRECTION & SPEED INDICATOR
WIND DIRECTION DIAL
WIND SPEED DIAL
TR
TR
CT
TX
SHADED-POLE FOLLOWUP MOTOR
AMPL.
M
WIND DIRECTION SUBASSEMBLY
TR
TX
ROLLER DISK INTEG.
SYNCHRONOUS MOTOR
M
WIND SPEED SUBASSEMBLY
WIND DIRECTION AND SPEED TRANSMITTER

140.60

Figure 15-7.—Block diagram of type-B wind direction and speed indicator system.

The type-B wind direction and speed indicator system may be modified by adding a synchro signal converter and a synchro isolation amplifier. The converter and amplifier convert the 60-hertz signal to a 400-hertz signal for those ships using special weapons systems.

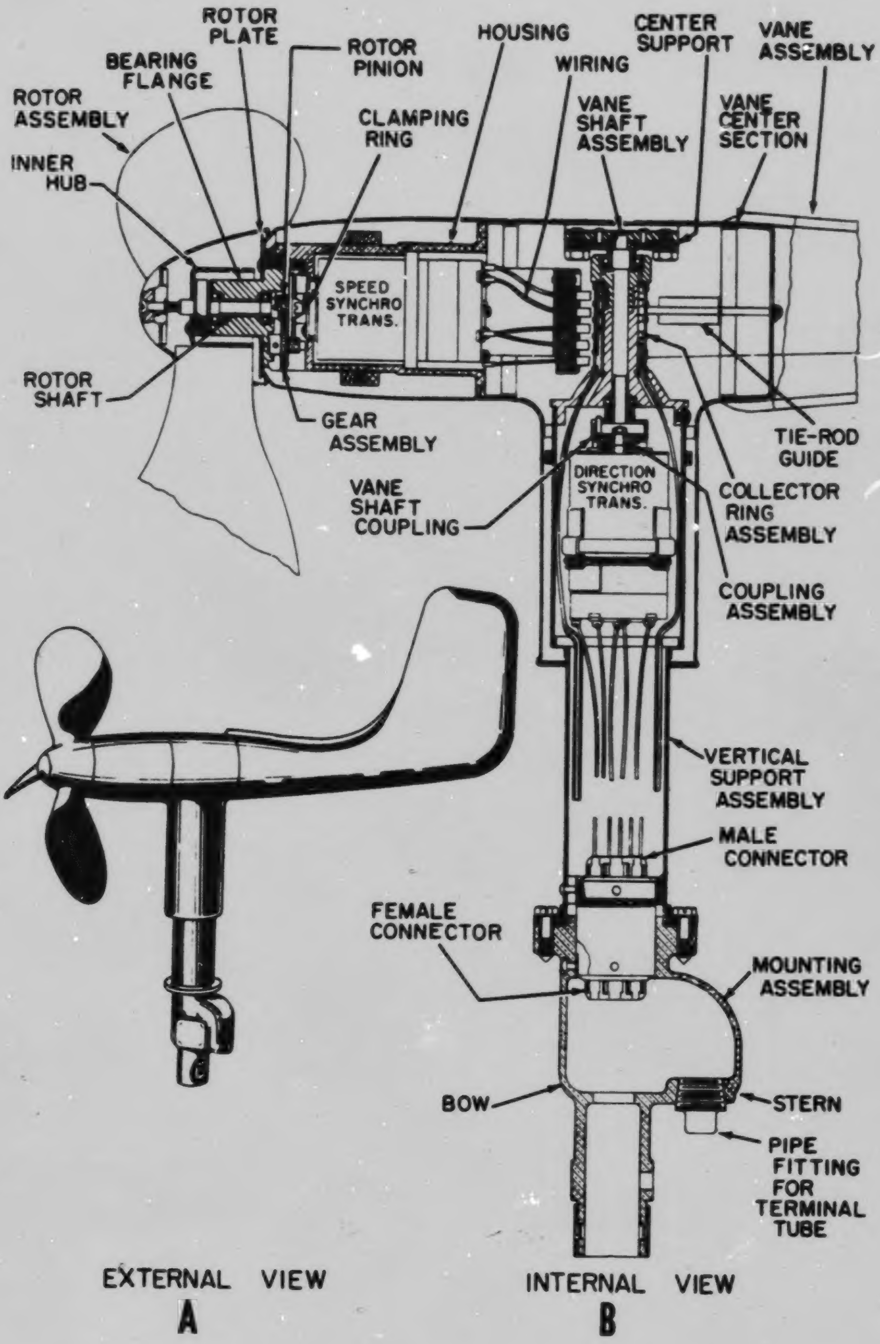
TYPE-B EQUIPMENT

Figure 15-7 shows a block diagram of a type-B wind direction and speed indicator system installed in a large ship. The system consists of a (1) wind direction and speed detector, (2) wind direction and speed transmitter, and (3) wind direction and speed indicator. Generally, two wind direction and speed detectors are mounted on the foremast, one on the port side and one on the starboard side. The wind direction and speed transmitter is installed in the IC room. The wind direction and speed indicators are installed in various navigational spaces as required by the type of ship.

Detector

The wind direction and speed detector (fig. 15-8) consists of a thin-gage monel metal housing formed into a streamlined wind vane with a relatively large tail surface mounted on a vertical support assembly. The rotor assembly, attached to the head of the vane is held directly into the wind by the vane assembly and converts the wind speed into rotary motion. The speed of rotation of the rotor assembly is proportional to the velocity of the wind striking the rotor blades.

The direction synchro transmitter, mounted in the vertical support assembly, is directly coupled to the vane so that when the wind positions the vane, the synchro transmitter is displaced the same angular amount. The angular


ROTOR PLATE
BEARING FLANGE
ROTOR ASSEMBLY
INNER HUB
ROTOR PINION
CLAMPING RING
HOUSING
WIRING
CENTER SUPPORT
VANE SHAFT ASSEMBLY
VANE CENTER SECTION
VANE ASSEMBLY
SPEED SYNCHRO TRANS.
ROTOR SHAFT
GEAR ASSEMBLY
TIE-ROD GUIDE
DIRECTION SYNCHRO TRANS.
VANE SHAFT COUPLING
COLLECTOR RING ASSEMBLY
COUPLING ASSEMBLY
VERTICAL SUPPORT ASSEMBLY
MALE CONNECTOR
FEMALE CONNECTOR
MOUNTING ASSEMBLY
BOW
STERN
PIPE FITTING FOR TERMINAL TUBE
EXTERNAL VIEW
A
INTERNAL VIEW
B

7.145

Figure 15-8. — Wind direction and speed detector.

positions are transmitted electrically to a synchro control transformer in the wind direction subassembly of the transmitter (fig. 15-7). Because wind directions are indicated in relative bearings, the direction synchro transmitter is set to electrical zero when the rotor assembly of the detector unit points to the bow of the ship.

The speed synchro transmitter, mounted in the head of the vane, is coupled through gears to the rotor assembly so that the synchro rotates 1 revolution for each 12.5 revolutions of the propeller. The reduced rotary motions are transmitted electrically to a synchro receiver in the wind speed subassembly of the transmitter unit (fig. 15-7). Electrical connections to the speed synchro are provided through collector rings and brushes (fig. 15-8).

The mounting assembly and the vertical support assembly are provided with flanges for bolting the two sections together. The detector is held in alignment by a mounting bolt that serves as a dowel. The incoming cable is brought into the unit through a watertight terminal tube in the bottom of the mounting assembly and is connected to a female connector in the top of this assembly. The leads for the synchros are connected to a male connector in the bottom of the vertical support assembly. Thus, the detector mechanism can be removed without disconnecting the incoming leads or disturbing the alignment.

Transmitter

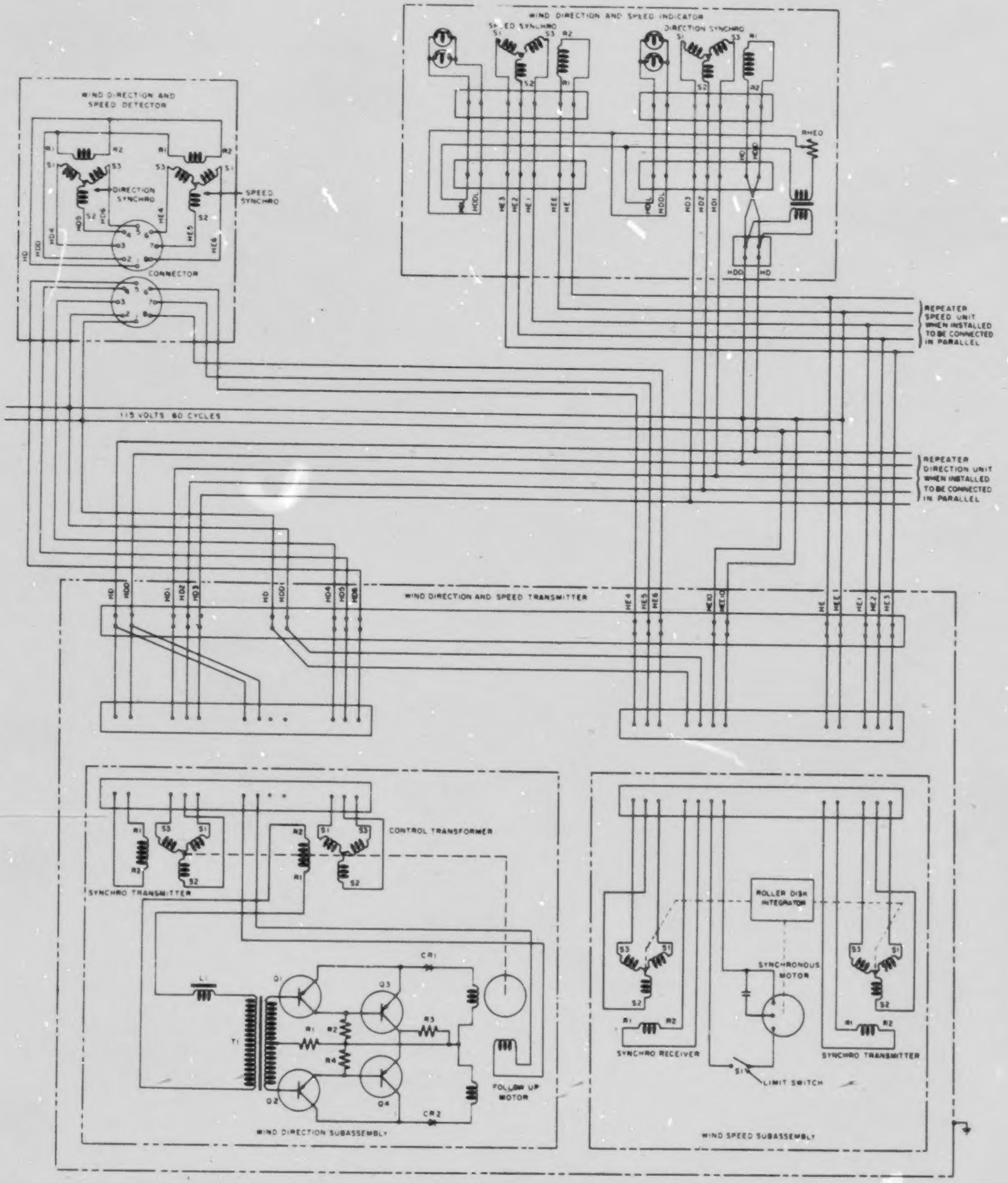
The wind direction and speed transmitter (fig. 15-7) consists of a wind direction subassembly and a wind speed subassembly mounted on individual baseplates to form a complete unit enclosed in a metal case designed for bulkhead mounting.

The wind direction subassembly is essentially a servo unit comprising a synchro control transformer, followup motor, and synchro transmitter. The synchro control transformer receives the angular displacements from the direction synchro transmitter in the detector. These angular displacements are amplified and fed to the followup motor which drives the synchro transmitter and control transformer through gears into correspondence with the synchro transmitter in the vane. The synchro transmitter transmits the angular displacements (which are damped by means of the gear assembly), at a predetermined rate of approximately 1.25 rpm to the synchro receiver in the associated wind direction subassembly of the remotely located indicator.

When the vane direction transmitter and the synchro control transformer rotors are in correspondence, the output of the control transformer is zero. When the vane changes its position, the two rotors are no longer in correspondence and a voltage is induced in the rotor of the control transformer. The output voltage from the rotor of the control transformer is either in phase or 180 degrees out of phase with the source (reference) voltage, depending on the direction in which the vane has turned. Thus, the phase of the control transformer reverses with respect to the transmitter reference voltage as the direction of displacement reverses. The magnitude of the control transformer output voltage represents the amount by which the shafts of the control transformer and the vane transmitter are out of correspondence. The direction in which the transmitter shaft is turned represents the phase of the control transformer output voltage which determines the direction of rotation of the followup motor.

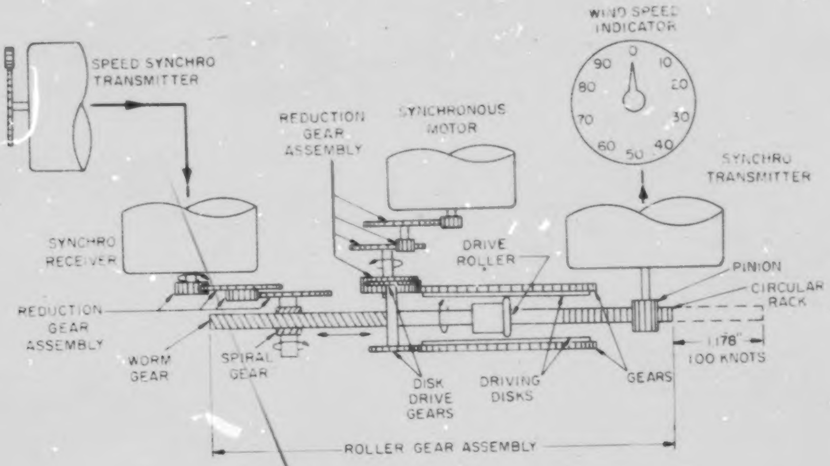
The signal from the control transformer (fig. 15-9) is fed to the input transformer T1 of the amplifier. The series inductor L1 in the primary of T1 compensates for the phase shift inherent in the control transformer so that the signal applied to the primary of T1 is exactly in phase or 180 degrees out of phase with the reference voltage. Transformer T1 also isolates any direct current in the circuit of the secondary winding from the synchro control transformer. The secondary of T1 is connected to the amplifier, consisting of the paralleled transistors Q1-Q2 and Q3-Q4 connected for push-pull operation. Transistors Q1 and Q2 are connected as emitter followers which offer a high impedance to T1, and thus prevent overloading of the synchro control transformer. The output of Q1-Q3 and Q2-Q4 is connected to the shading windings CCW and CW of the shaded-pole followup motor through rectifiers CR1 and CR2, respectively. When the vane changes its position, the upper section (Q1-Q3), or the lower section (Q2-Q4), conducts and applies the amplifier output to the CCW or CW winding to drive the followup motor in the direction corresponding to that in which the vane transmitter rotor is displaced. The followup motor positions the synchro transmitter and drives the rotor of the control transformer into correspondence with the vane transmitter rotor to null the signal and stop the motor.

The rectifiers CR1 and CR2 between the transistors and shading windings of the followup motor restrict the direction of current flow in the transistors and shading windings. The resistors


WIND DIRECTION AND SPEED INDICATOR
SPEED SYNCHRO
DIRECTION SYNCHRO
S1
S2
S3
R1
R2
RHEO
HDD
HD
HDDL
HDL
HD1
HD2
HD3
HE
HEE
HE1
HE2
HE3
REPEATER SPEED UNIT WHEN INSTALLED TO BE CONNECTED IN PARALLEL
WIND DIRECTION AND SPEED DETECTOR
DIRECTION SYNCHRO
SPEED SYNCHRO
CONNECTOR
HD4
HD5
HD6
HE4
HE5
HE6
115 VOLTS 60 CYCLES
REPEATER DIRECTION UNIT WHEN INSTALLED TO BE CONNECTED IN PARALLEL
WIND DIRECTION AND SPEED TRANSMITTER
SYNCHRO TRANSMITTER
CONTROL TRANSFORMER
L1
T1
Q1
Q2
Q3
Q4
R3
R4
CR1
CR2
FOLLOW UP MOTOR
WIND DIRECTION SUBASSEMBLY
ROLLER DISK INTEGRATOR
SYNCHRONOUS MOTOR
SYNCHRO RECEIVER
SYNCHRO TRANSMITTER
LIMIT SWITCH
WIND SPEED SUBASSEMBLY

7.144

Figure 15-9. — Wiring diagram of type-B wind direction and speed indicator system.



7.147

Figure 15-10. —Wind speed subassembly.

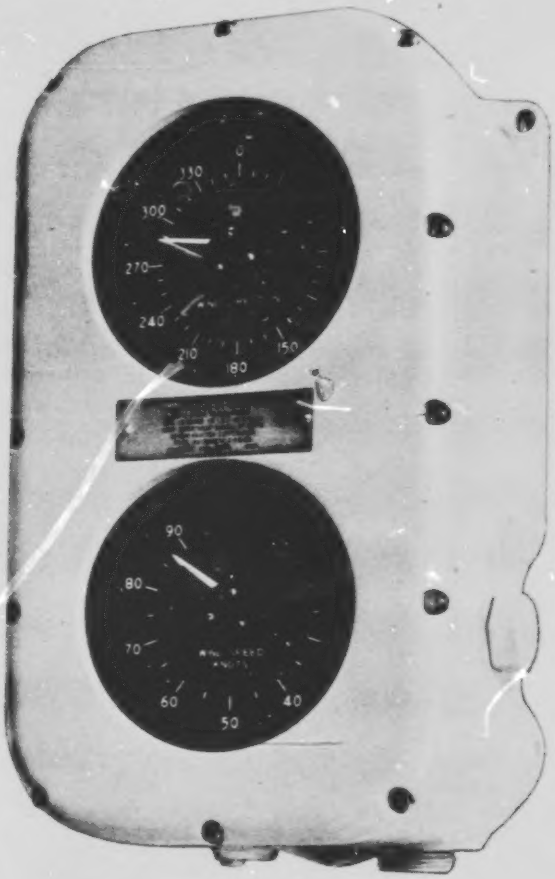
R2 and R3 connected in the base circuits of transistors Q3 and Q4 serve to provide low resistance shunt paths for the collector leakage currents which may reach excessive values at high ambient temperatures. Resistor R1, connected in the common emitter return circuit, provides degenerative bias to further stabilize the operating points of transistors Q3 and Q4. Resistor R1 also serves to drive the nonconducting transistor to cutoff when an error signal is present at the other transistor base, thereby improving the performance at all ambient temperatures.

The wind speed subassembly (fig. 15-10), is essentially a roller disk integrator comprising a synchro receiver, a roller gear assembly with worm and circular rack, constant speed motor, and synchro transmitter. The synchro receives the rotary motions from the vane speed transmitter, the roller gear assembly converts the rate of these rotary motions into proportional angular displacements, and the synchro transmits these displacements to the synchro receiver in the associated wind speed subassembly of the remotely located indicator.

The synchro receiver, which rotates at the same speed as the synchro speed transmitter in the detector, transmits the rotary motion through reduction gears to the worm of the roller gear assembly. This gear reduction terminates with a spiral gear that engages the worm of the roller gear assembly. The action of the spiral gear against the worm of the roller gear assembly is that of a pinion on a rack which drives the drive roller away from the center of the two driving disks in a linear motion. However, the drive roller with its integral worm and circular rack are rotated by the two driving disks, which turn in opposite directions, by a constant speed (synchronous) motor through reduction gears and the two disk drive gears.

The speed of the circular motion of the drive roller depends on the position of the roller with respect to the center of the driving disks. The speed of the drive roller increases as the roller approaches the edge of the disk. Hence, the drive roller receives circular motion and linear motion simultaneously. Although the driving action of the spiral gear against the worm tends to drive the roller away from the center of the two disks, the motion resulting from the revolving of the worm engaging the spiral gear is toward the center of the disks. When the circular motion and the linear motion balance each other, the drive roller assumes a position of displacement from the center of the disks that is proportional to the rotor speed of the speed transmitter in the detector.

The drive roller is attached to the roller gear assembly shaft and positions this shaft laterally. The circular rack of the roller gear assembly engages a pinion on the shaft of the synchro transmitter, thereby transforming linear motion into



7.148
Figure 15-11.—Wind direction and speed indicator.

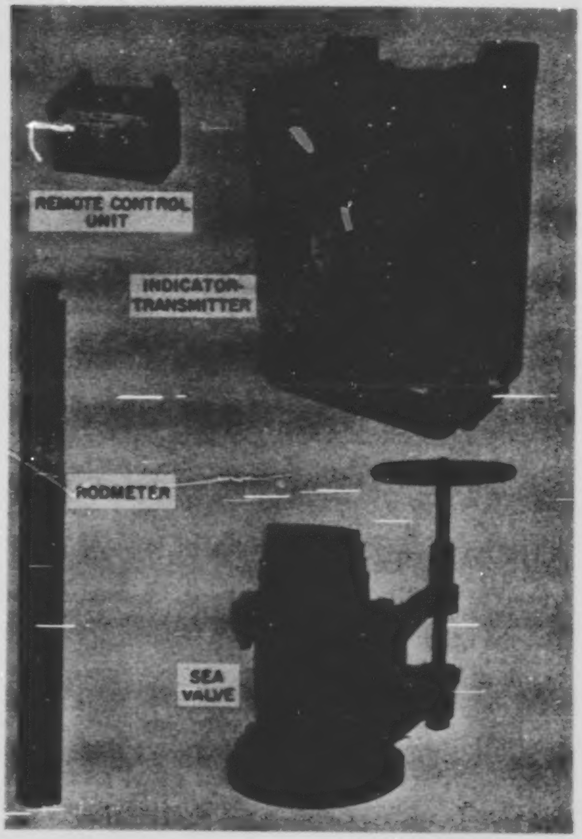
angular motion. The angular motion is transmitted to the wind speed subassembly in the remotely located indicator. The speed synchro transmitter is set to electrical zero when the wind speed is zero.

A low-limit switch, S1, (fig. 15-9) is provided to open the circuit to the synchronous motor when the drive roller is at the center of the driving disks at zero wind speed. As the roller nears the center of the disks, the end of the worm gear forces a bell crank (not shown) to open switch, S1, and deenergize the circuit to the synchronous motor. This switch saves needless wear on the disks and roller when there is no wind speed to be indicated.

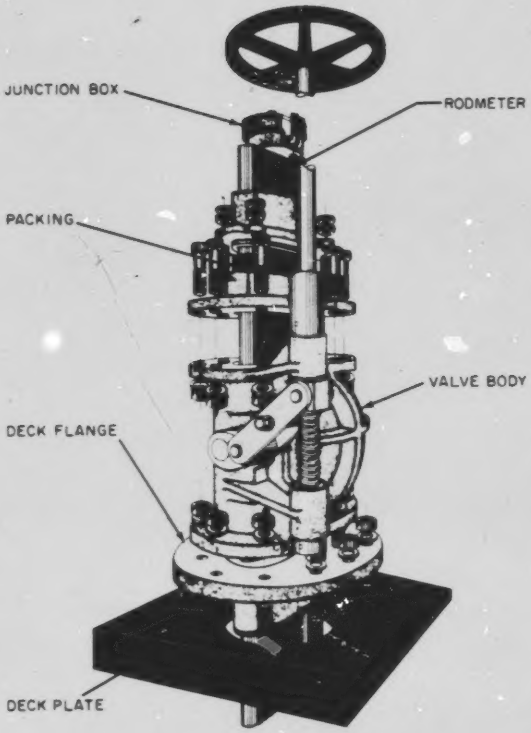
Indicator

The wind direction and speed indicator (fig. 15-11), is a dual unit consisting of a wind direction subassembly and a wind speed subassembly. The two subassemblies are identical except for the dials. Each consists of a synchro receiver indicating on a fixed dial by means of a revolving pointer directly attached to its shaft. The subassemblies are mounted on individual baseplates and enclosed in a metal housing to form a complete wind direction and speed indicator unit.

The direction synchro receiver receives the angular displacements from the synchro transmitter in the direction subassembly of the transmitter unit, and indicates these displacements



140.158
Figure 15-12.—Major components of the underwater log system.



140.159

Figure 15-13.—Exploded view of the sea valve and packing assembly with rodmeter installed.

on the direction dial. The direction dial is graduated in 10° intervals from 0° to 360°.

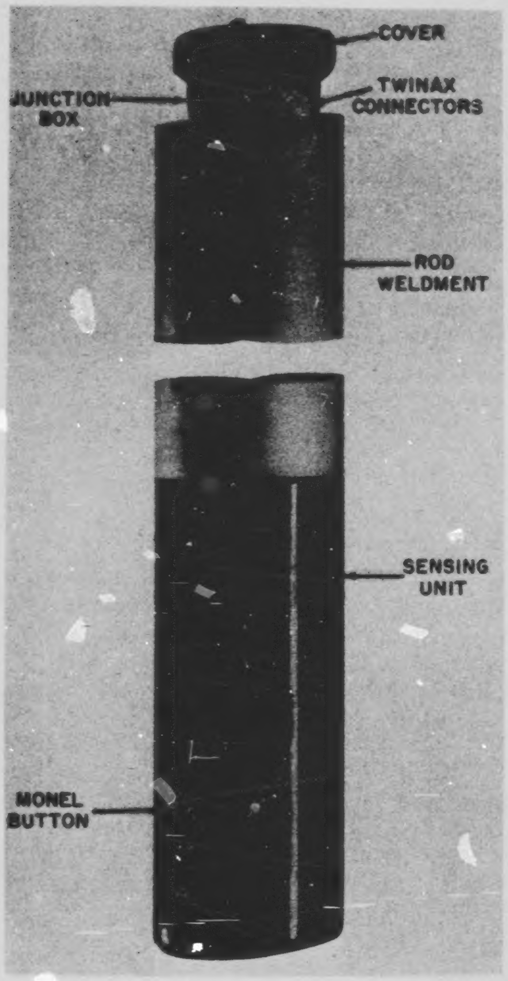
The speed synchro receiver receives the angular displacements from the synchro transmitter in the speed subassembly of the transmitter unit, and indicates these displacements on the speed dial. The speed dial is graduated in 5-knot intervals from 0 to 100 knots.

The dials and pointers are red illuminated. Dial illumination for each subassembly is provided by two lamps in parallel supplied from a 115/6-volt transformer inside the housing. A knob on the side of the case controls a rheostat for varying the intensity of the illumination.

MAINTENANCE

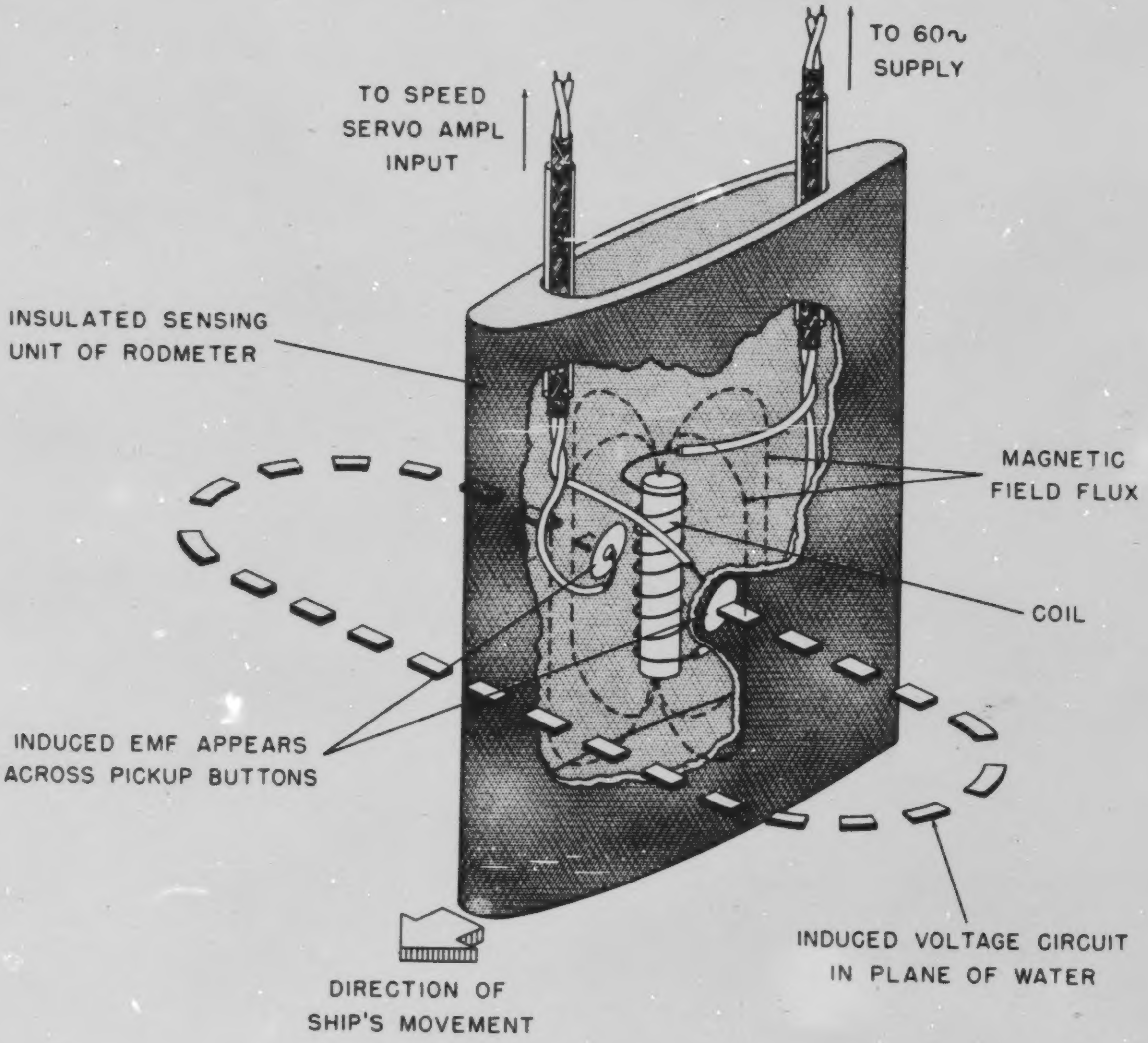
Preventive maintenance for the type-B wind direction and speed indicator system consists of periodic inspections, cleaning, and lubricating. Observe the indicators periodically; uneven movement of the pointers indicates possible trouble. By comparing the pointer movement of one indicator with another you can determine if the trouble is in a single indicator or in the system.

Periodically and after exposure to high winds, inspect the detector mounting and tighten the mounting bolts if necessary. Turn the rotor by hand to ensure that it turns freely. Rotate the vane through 360° in both directions to ensure it rotates freely.



27.272

Figure 15-14.—Rodmeter.


TO SPEED
SERVO AMPL
INPUT
TO 60~
SUPPLY
INSULATED SENSING
UNIT OF RODMETER
MAGNETIC
FIELD FLUX
COIL
INDUCED EMF APPEARS
ACROSS PICKUP BUTTONS
INDUCED VOLTAGE CIRCUIT
IN PLANE OF WATER
DIRECTION OF
SHIP'S MOVEMENT

27.273

Figure 15-15. —Sensing unit.

Every six months, or as specified by the Planned Maintenance Subsystem Manual, clean and lubricate the detector and transmitter. The indicators require no lubrication.

UNDERWATER LOG SYSTEM

The underwater log system, circuit Y, measures and indicates the speed of the ship and the distance traveled through the water. It also transmits the information to the various weapons and navigational systems as required.

The electromagnetic type of underwater log system is currently in use throughout the Navy. The major components of this system are the sea valve, rodmeter, indicator-transmitter, and remote control unit (fig. 15-12).

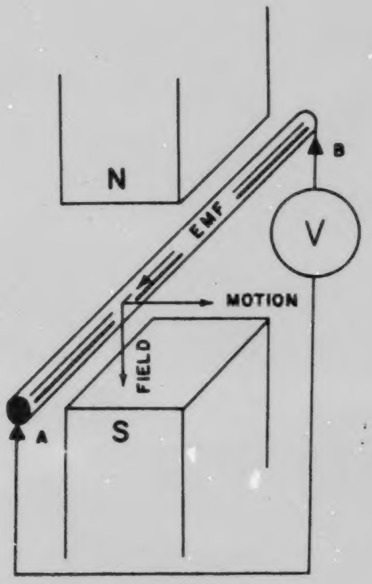
SEA VALVE AND RODMETER

Mounted in the hull of the ship, the sea valve and packing assembly (fig. 15-13) provides a watertight support for the rodmeter, enabling it to retract or extend through the open sea valve. The sea valve also seals the hull when the rodmeter is removed. This valve has no function relating to the production, transmission, flow, or conversion of data in the underwater log system.

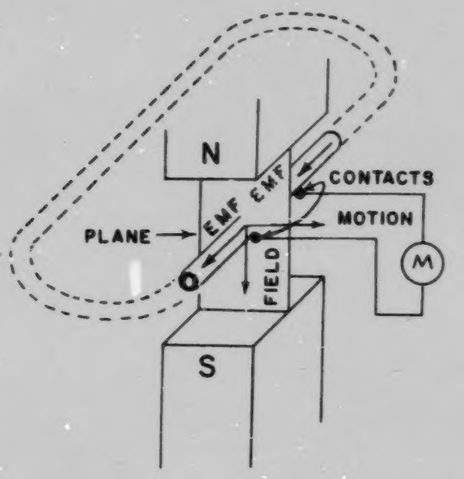
The rodmeter, approximately six feet long and made of corrosion-resistant Monel metal, passes through the open sea valve. The main components of the rodmeter are the rod weldment, the junction box, and the sensing unit.

The rod weldment makes up most of the length of the rodmeter. It is a hydrofoil cross section, nickel-copper, watertight tube. The sensing unit is cemented to the lower end of the rod weldment, and the junction box is bolted to the upper end. Two shielded electrical cables connected to the sensing unit pass through the rod weldment and terminate in the twinax connectors.

The sensing unit is a plastic molding (boot) made of an epoxy resin mixed with glass fiber. In it are imbedded a coil and two Monel metal buttons. See figures 15-14 and 15-15.



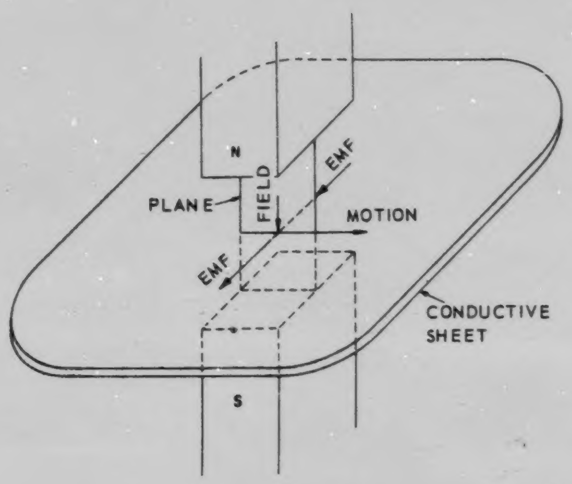
27.274
Figure 15-16.—Voltage induced in a conductor.



27.275
Figure 15-17.—Measurement of induced voltage.

Electromagnetic Induction

When a conductor is made to move in a magnetic field so as to cut the lines of field flux, an EMF is induced in the conductor. The EMF induced is equal to the product of the



27.276
Figure 15-18.—Measurement of voltage in a conductive sheet.

flux density in which the conductor is moving, the length of the conductor, and the velocity of the conductor.

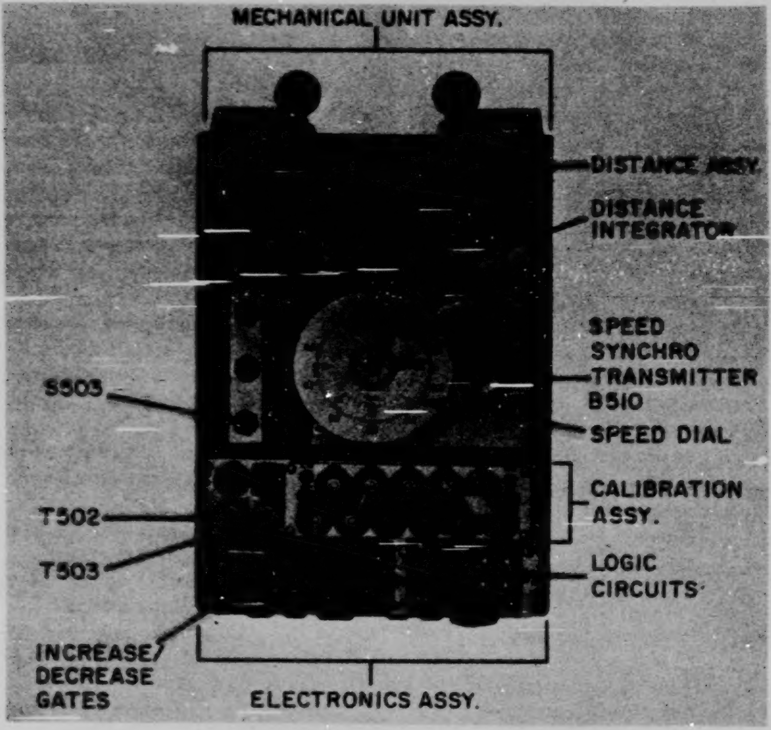
There are two methods that may be used to detect the magnitude of the voltage induced in the conductor due to its velocity through the magnetic field. Measure the voltage (first method) at the ends of the conductor, points A and B in figure 15-16.

Using the second method, close the conductor upon itself outside the magnetic field, as shown by the dotted lines in figure 15-17. Then cut the conductor by a nonconducting plane parallel to the direction of motion and to the lines of flux, and by means of suitable contacts on each side of the plane measure the voltage across the plane. The conductor, as it moves through the magnetic field, cuts lines of flux on both sides of the plane, and a voltage proportional to the velocity of the conductor is induced in the conductor on both sides of the plane.

If the conductor shown in figures 15-16 and 15-17 is replaced by a sheet of conductive material, as shown in figure 15-18, a voltage will be induced in the conductive sheet in a manner similar to that shown in figure 15-16. If a plane could be passed through the conductive sheet (fig. 15-18), the magnitude of the voltage induced in the sheet could be measured, as shown in figure 15-17. The portion of the sheet that lies outside of the magnetic field acts as a closed loop around the insulating plane. Therefore, the total voltage induced in the conductive sheet could be measured across the plane.

Sensing Unit

The sensing unit of the rodmeter operates on the principle of electromagnetic induction. An a-c voltage excites the coil (fig. 15-15) located in the plastic shell on the outboard end of the rodmeter, thus creating a magnetic



7.153(140B)

Figure 15-19. — Indicator-transmitter (cover removed).

field uniformly distributed around the rodmeter. The magnetic field is in time phase with alternating current flowing in the coil. That is, the flux density varies each half cycle with the coil current, and the direction of the magnetic field reverses as the direction of the coil current reverses each half cycle. Therefore the induced voltage is an alternating voltage. The magnitude of the a-c voltage generated in the conductor is proportional to both the flux density and the speed of the ship through the water.

The water, which is a conductor, creates a closed path in its natural flow about the rodmeter. The water is cut by the nonconducting plane, which is the plastic shell of the rodmeter. As the magnetic field moves through water, the water on both sides of the rodmeter is being cut by lines of flux, and a voltage proportional to the speed of the ship is generated on both sides of the rodmeter. The pickup buttons (fig. 15-15), located on each side of the rodmeter make contact with the water and pick up the voltage being generated in the water.

The magnitude of this voltage is affected by whether the flow of the water past the rodmeter is smooth or turbulent, by eddies from the hull of the ship, and by other minor effects. Some of these effects are corrected by adjustment of compensating circuits in the indicator-transmitter.

INDICATOR-TRANSMITTER

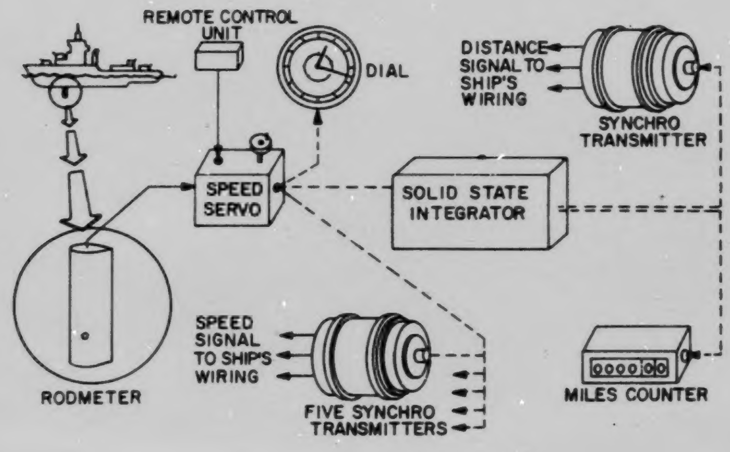
The indicator-transmitter is housed in a bulkhead-mounted, rectangular, cast-aluminum case with sheet aluminum cover. It contains all the electrical and electromechanical parts in the log equipment except the components in the rodmeter and remote control unit. It is electrically connected to the rodmeter by two 2-conductor cables, with braided shields, which terminate in connectors that fit receptacles in the lower part of the case. The principal components of the indicator-transmitter are (1) power supply, (2) the electronics assembly, (3) the mechanical unit assembly, and (4) the calibration assembly. See figure 15-19.

Power Supply

Two d-c voltages, one high and the other low, make up the power supply for the indicator-transmitter. The low voltage supply is associated with the speed servo system, the high voltage supply, with the distance system. Both supplies use full-wave bridge rectifiers.

Electronics Assembly

The electronics assembly is located in the lower part of the indicator-transmitter case. It contains most of the nonrotating electrical components of the indicator-transmitter. The



7.152(140B)

Figure 15-20. — Block diagram of electromagnetic type underwater log system.

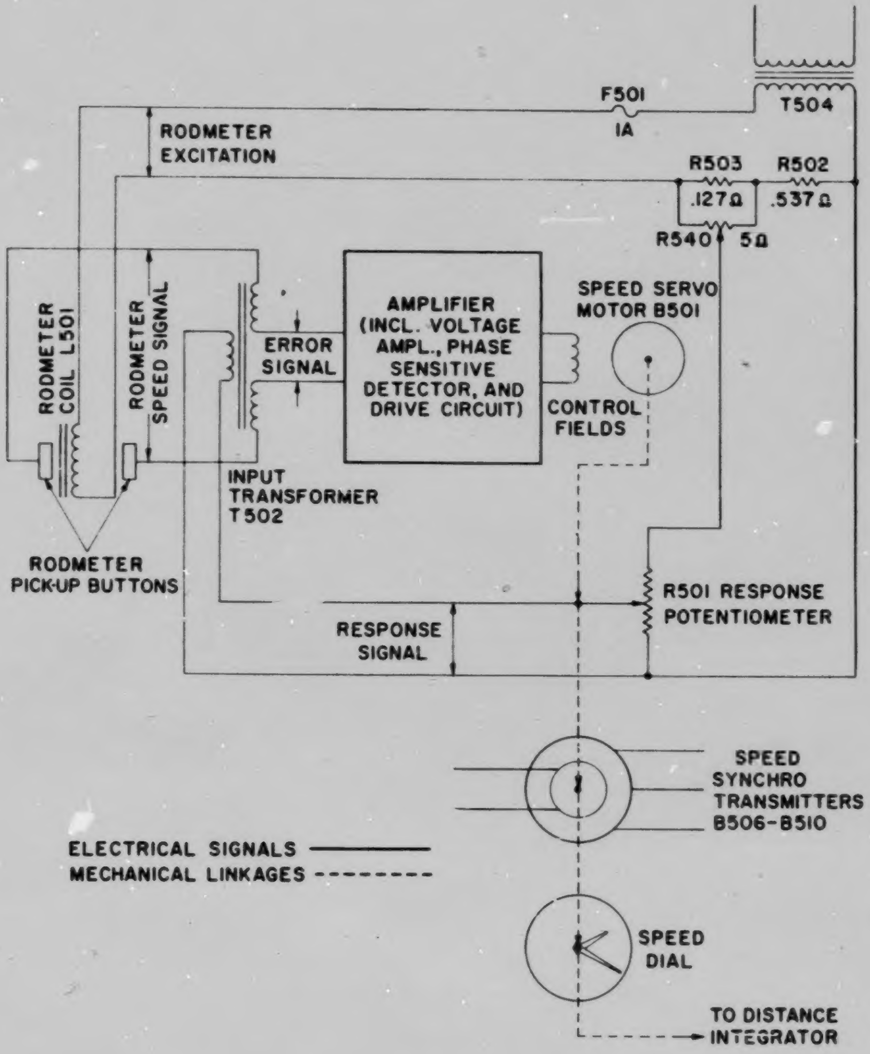
hinged portion of this assembly swings out from the case of provide access to the bottom of the case for troubleshooting and servicing.

Mechanical Unit Assembly

The mechanical unit assembly contains all the moving parts of the system, including all motors, indicators, synchros, switches, and drive circuit board. The chassis of the mechanical unit assembly is also hinged and the door section contains all gearing and electromechanical parts of the speed servo, integrator, and distance servo.

Calibration Assembly

The calibration assembly is located above the electronics assembly in the lower half of the indicator-transmitter case. It consists of


F501
1A
T504
RODMETER EXCITATION
R503
.127Ω
R502
.537Ω
R540
5Ω
RODMETER COIL L501
RODMETER SPEED SIGNAL
ERROR SIGNAL
AMPLIFIER (INCL. VOLTAGE AMPL., PHASE SENSITIVE DETECTOR, AND DRIVE CIRCUIT)
SPEED SERVO MOTOR B501
CONTROL FIELDS
INPUT TRANSFORMER T502
RODMETER PICK-UP BUTTONS
R501 RESPONSE POTENTIOMETER
RESPONSE SIGNAL
SPEED SYNCHRO TRANSMITTERS B506-B510
ELECTRICAL SIGNALS
MECHANICAL LINKAGES
SPEED DIAL
TO DISTANCE INTEGRATOR

7.154(140B)

Figure 15-21. —Simplified functional schematic of speed servo.

a series of potentiometers used to calibrate the system when the ship is making measured mile runs.

PRINCIPLES OF OPERATION

The underwater log system comprises the components shown in figure 15-20. The system functions as follows: The rodmeter produces an a-c signal voltage proportional to the ship's speed through the water. This signal is fed to the speed servo, which drives the speed synchro transmitters, the dual-pointer dial, and the solid-state integrator. The integrator converts the input from the speed servo into a distance-traveled output which drives a synchro-transmitter and a 6-drum counter to display distance traveled in nautical miles. A test signal circuit (not shown) performs no function in normal equipment operation, but provides simulated signals that can be used in checking the functioning of the system.

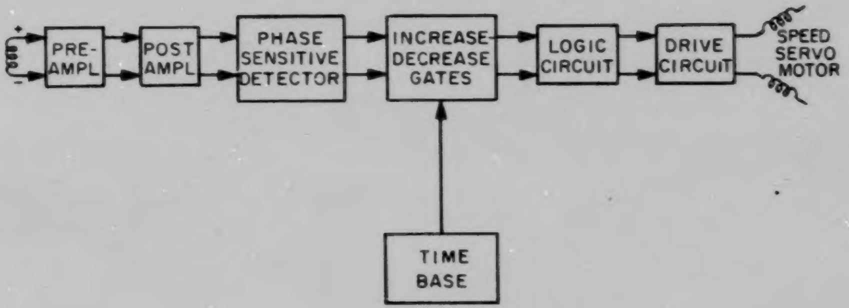
Speed Servo

The speed servo translates the signal voltage generated by the rodmeter into a mechanical angular output that is fed to the speed dial, speed synchro transmitter, and distance integrator. The input transformer T502 (fig. 15-21) functions as an error detector. It receives the speed voltage generated by the rodmeter and a response signal which is an indication of the present position of the servo output. When an error exists between the position of the load and the position called for by the speed signal, an error signal is generated by the input transformer. The error signal is fed to the amplifier which produces the power necessary to drive the speed servomotor B501 in accordance with the error signal. When the load is correctly positioned in accordance with the speed signal, the error voltage is zero. The response signal is initially produced by dropping resistors R502 and R503 in the rodmeter coil supply. The magnitude of the response signal is adjusted by the response potentiometer R501 which is driven through gears by the speed servo motor B501.

Pitch, roll, and ship's motion other than forward motion produce output signals from the rodmeter. The magnitudes of the signals vary, being dependent upon sea state primarily. The variable output causes the speed servo to constantly run up and down in trying to follow the signals. You can change the response of the speed servo by switching the slow/fast response switch located in the indicator-transmitter assembly. In the "slow" position the speed servo is unable to follow any variations in the rodmeter that exceed 8 knots/minute and, as a result, the speed outputs of the log are "smoothed."

AMPLIFIER.—The amplifier (fig. 15-22) consists of a preamplifier, postamplifier, phase sensitive detector, increase-decrease gates, logic circuit, and drive circuit. Each amplifier component is on a separate printed circuit board, and is completely transistorized.

The preamplifier is a differential amplifier having a gain of about 300. Normally the error signal being amplified is about 6 microvolts which calls for a small tolerance in stray voltage pickup levels. Shielded input leads and



140.160

Figure 15-22.—Block diagram of the speed servo amplifier.

an enclosure around the amplifier reduce the stray voltage pickup to acceptable levels. The postamplifier is a double-ended voltage amplifier with a voltage gain of about 25.

The phase sensitive detector converts the amplified a-c error signal to a d-c voltage proportional to the error signal. The detector is sensitive not only to the amplitude of the error voltage but also to the phase with respect to a reference. The increase-decrease gate allows pulses from the time base to pass through depending on the amplitude and polarity of the error. These pulses are shaped and amplified.

The logic circuit consists of a 4-state counter that conducts in response to pulses from the increase-decrease gate. The motor will step counterclockwise for increasing pulses and clockwise for decreasing pulses. The drive circuit consists of four double emitter followers capable of driving the speed servo motor without overloading the logic circuit.

The time base is a relaxation oscillator producing two frequencies, one for fast and one for slow speed servo operation. The frequencies make it possible to select response speeds for the speed servo that represent 40 knots/minute or 8 knots/minute. The slow speed is used when ship's motion (other than forward motion) or water turbulence is causing the rodmeter signal to oscillate and it is desirable to smooth out the oscillation. The speed servo cannot follow any change of more than 8 knots/minute when in the slow speed mode.

SERVOMOTOR.—The speed servo output is mechanical and is driven by stepping motor B501 (fig. 15-21) which has a permanent magnet rotor and four stator field windings. The rotor has 50 teeth which gives the motor 100 poles. This motor is capable of turning 1.8° per step or 200 steps in one revolution in response to d-c inputs to its field windings from the drive circuit.

The motor runs in the direction required to eliminate the error, that is, reduce to zero the difference between rodmeter signal and response signal. In doing so, the motor drives the speed servo gearing that positions the two pointers on the speed dial, drives five speed synchro transmitters, drives the integrator's resolver shaft, and positions the response potentiometer.

Speed Dial

Ship speed as transmitted by the speed servo is indicated on a dial on the face of the indicator-transmitter. The dial is a clock-type indicator with the short hand making one complete revolution for change in speed of 40 knots, and the long hand making one complete revolution for a change in speed of 1 knot. The hands are driven through gearing by the speed servomotor. Speed is transmitted on 60-and 400-Hz synchros at speeds of 10, 40, and 100 knots per turn.

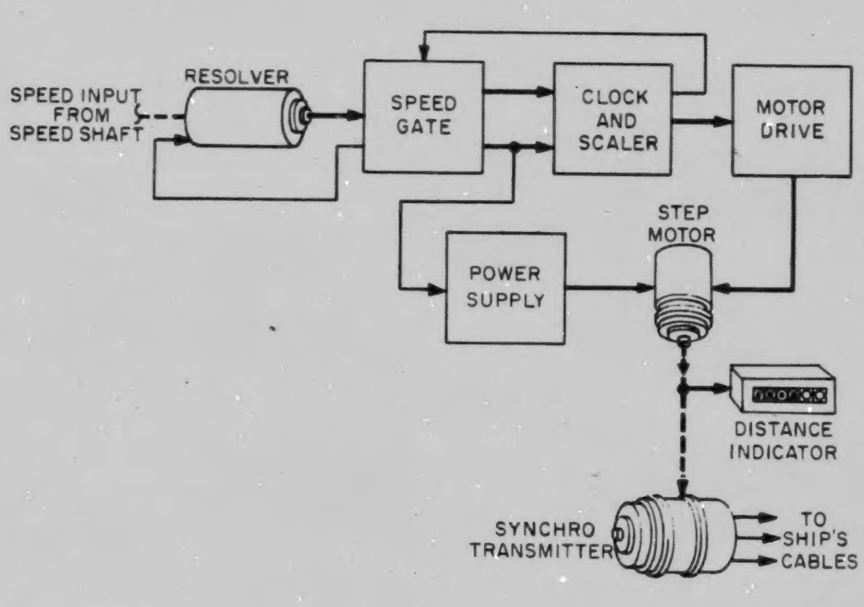
Integrator

The integrator is an electronic device that contains integrated solid-state circuits and miniaturized components. It comprises a precision data transmission resolver, a step motor, four printed circuit boards, a distance traveled indicator, and a synchro transmitter (fig. 15-23). The integrator carries out the mathematical process of integrating speed with respect to time to obtain distance. The resultant signal of integration is a series of pulses whose frequency is a function of speed. These pulses drive the step motor which is mechanically coupled to the distance traveled indicator (nautical miles counter) and to the synchro transmitter that sends distance information to remote locations.

The resolver phase shifts the signal from the speed gate as a function of the resolver's shaft position. Any speed will displace the resolver shaft from the zero degree reference since it is mechanically coupled to the speed shaft. The phase-shifted signal is then routed to the speed gate where it is converted to a pulse that has an on/off time that varies with the amount of phase shift. The variable duty-cycle signal is then routed to the clock and scaler where it is used as a gating signal, and to the power supply where it is used to control a current regulation circuit. A reference signal is also routed to the clock and scaler from the speed gate. The clock and scaler uses the gating signal to gate a 1.728-mHz signal at the same rate as the on/off time of the variable duty cycle signal. The clock and scaler develops a square-wave signal whose frequency is proportional to speed. This signal is then routed to the motor drive which will turn the step motor faster or slower depending on ship's speed. The operating voltage for the step motor is developed by the power supply which varies the voltage as a function of speed. The speed motor directly drives the distance indicator, and the distance synchro transmitter.

Miles Counter

The miles counter, or distance indicator, is a six-place odometer that registers to 1/100



140.161

Figure 15-23.—Block diagram of the solid-state integrator.

nautical mile. Its maximum indication is 9,999.99 nautical miles. A reset knob enables the counter to be turned back to zero, if necessary.

REMOTE CONTROL UNIT

By means of the remote control unit, speeds can be set on the indicator-transmitter from a remote location, such as the engineroom. This unit makes it possible to use the underwater log system as a dummy log in certain situations. For example, the ship is operating in shallow water and the rodmeter must be retracted to keep from damaging it.

In the remote control unit, an increase-decrease switch is connected in parallel with the increase-decrease switch S503 (fig. 5-19) in the indicator-transmitter. Both switches are center-off, spring-return, three-position switches for connecting the time base output to either the increase or decrease input of the logic circuit and, as a result, drive the speed motor so as to increase or decrease the speed setting.

A red light on the remote control unit tells the operator that the log has been switched to dummy log operation. While watching the speed indicator he can set speed, by means of the increase-decrease switch, until the indicator-transmitter is at the desired speed setting. The system functions as a dummy log, transmitting speed and distance synchro outputs as in normal operation. The system may be switched to dummy log operation only at the indicator-transmitter, but speed may be set at either the remote control unit or the indicator-transmitter. When the remote control unit is located in the engineroom, near a remote speed indicator, propulsion shaft speed may be used to approximate ship's speed.

SALINITY INDICATOR SYSTEM

The salinity indicator system, circuit SB, is used to indicate the amount of salinity in water systems aboard ship. The system is a necessity aboard ship because all fresh water, particularly when underway, is made from sea water. Excessive salinity in the boiler feed water causes pitting of the tubes and rapid deterioration due to electrolysis. Salinity indicators are usually provided in the enginerooms and the firerooms for checking the condensate from the main and auxiliary condensers. They are also provided for the evaporator plants to indicate the degree of purity of the fresh water and condensate at various selected points in the distilling system.

The operation of the salinity indicator system is based on the principle that an increase of the electrolytic impurities (principally salt) in water increases the electrical conductivity of the water and conversely, that a decrease in the impurities increases the electrical resistance of the water. If two electrodes are immersed in the water being tested and a stable alternating voltage is applied across the electrodes, a stable alternating current will flow, provided the impurity content and the temperature of the water remain unchanged.

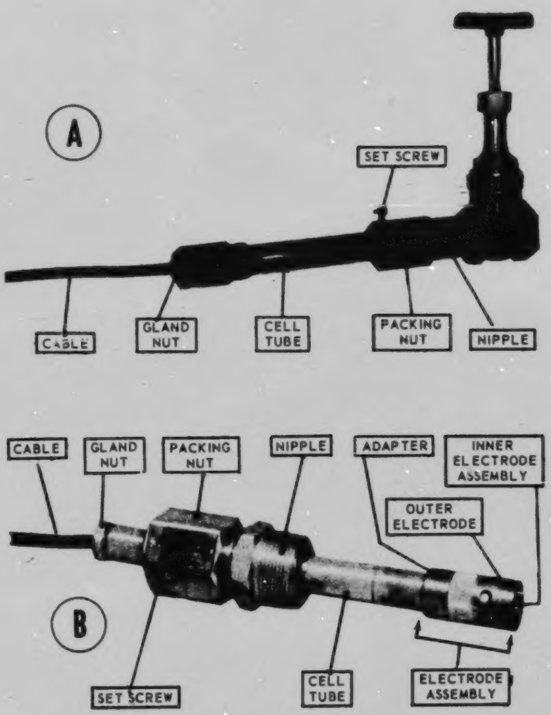
The amount of current flow is indicated on a meter, the scale of which is graduate in equivalent parts per million. If the saline content of the water increases because salt water leaks into the system or because the operation of the distilling plant becomes faulty, the conductivity between the electrodes increases and the meter reading increases an amount that is proportional to the increase in salinity.

A complete salinity indicator system consists of one or more salinity cells and an indicator panel. The salinity cells measure the conductivity of the water and transmit the measurements of the salinity indicator panel. The salinity indicating meter provided on the panel has a pointer which moves over a logarithmic scale calibrated in parts per million (ppm) of chloride. Each salinity cell including the associated circuits, indicators, and switches constitute one salinity channel.

SALINITY CELL AND VALVE ASSEMBLY

The salinity valve is a standard 1 1/4-inch cast-bronze wedge-seated valve with an externally threaded stem (fig. 15-24A). It is rated at 125 psi for steam pressure and is hydrostatically tested to 200 psi. The valve is fitted into the water system piping by means of a standard approved tee and provides a means of shutting off the water when withdrawing the salinity cell for cleaning and inspection.

The salinity cell is a self-contained unit consisting of a nipple, packing nut, cell tube, and electrode assembly (fig. 15-24B). The cell tube provides a means of extending the electrode assembly through the valve and is connected to the tee through the nipple and packing nut to form a watertight seal. The packing nut has a set screw that screws into a groove in the cell tube to prevent axial displacement of the tube by the hydrostatic pressure. A steel ring stop on the cell tube, between the packing nut and nipple, locates the cell properly in the piping.



7.150

Figure 15-24. —Salinity cell and valve assembly.

A 6-foot, 3-conductor cable connects the cell to the salinity indicating panel and the ship's 115-volt 60-hertz power. The cable is secured to the cell by means of a gland nut.

The electrode assembly comprises the inner electrode, adapter, automatic temperature compensator, and the outer electrode. The inner electrode is a hollow platinum-coated brass cylinder closed at the forward end. It is held in the adapter by means of a spring-loaded nut on the end of the inner electrode holder. A solder lug under this nut connects the white conductor of the incoming cable.

The outer electrode is a hollow brass cylinder the inside of which is coated with a thin layer of platinum. This electrode screws onto the adapter which in turn screws onto the cell tube. It is pierced with holes to vent the gases trapped in the space between the electrodes and to allow for free circulation of the water. The connection for the outer electrode is made by soldering the green conductor of the incoming cable into the hole provided in the cell tube.

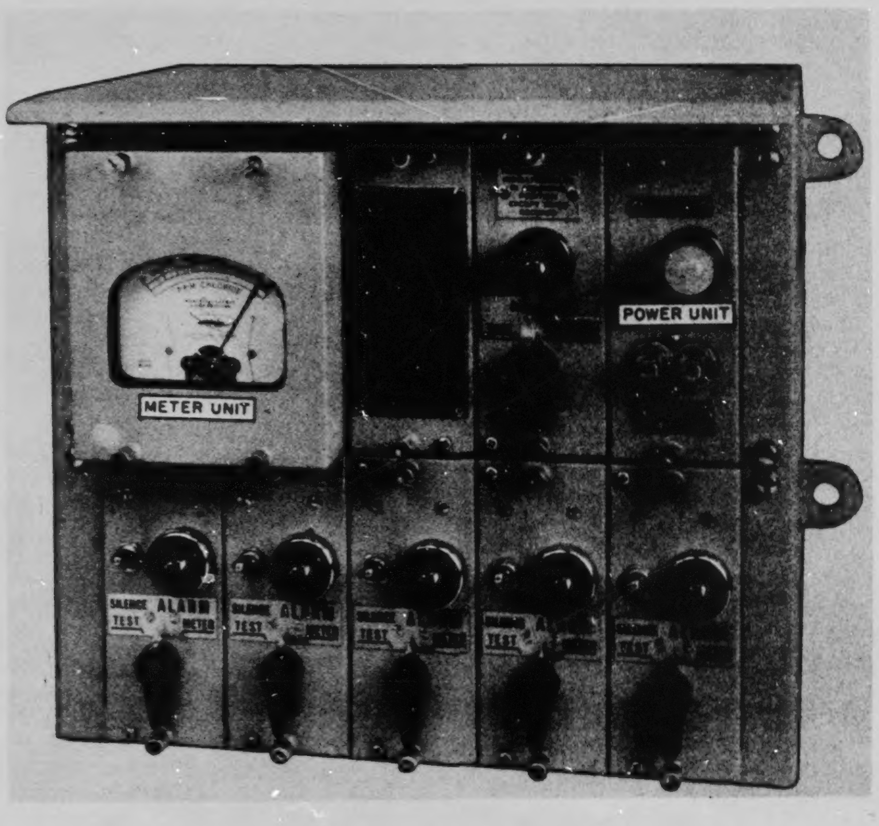
The automatic temperature compensator is a small circular disk located within the inner electrode to automatically compensate for changes in temperature through a range of 40°F to 250°F. It consists of a material having a negative temperature coefficient of resistance. The material has the same resistance temperature characteristics as dilute solutions of sea water. The conductance between the inner and outer electrodes is balanced by the conductance of the temperature in an electrical ratio circuit in such a way that the alarm point signal is independent of changes in water temperature. One side of the compensator disk is soldered to the closed end of the inner electrode and the other side has a lead brought out through the inner electrode holder to the black conductor of the incoming cable.

SALINITY INDICATOR PANEL

The salinity indicator panel (fig. 15-25) is designed to function in a system having five salinity cells, external alarm bells, and two solenoid trip valves. The panel contains a power unit, meter unit, five salinity cells, valve position and meter test unit, and a relay unit. The units are of the plug-in type to facilitate removal for inspection and repairs.

Power Unit

The ship's 115-volt 60-hertz power is applied to the salinity indicator panel through the power



7.151

Figure 15-25.—Salinity indicator panel.

unit (fig. 15-25). The power unit is not a plug-in type, but is wired directly onto the panel. It is provided with a white power-on indicator lamp, two fuse holders, and two blown-fuse indicators. The two fuses protect only the salinity cell and the alarm circuit wiring. The power circuits to the solenoid-operated control valves are not fused.

Meter Unit

The meter unit (fig. 15-25) measures the specific electrical conductivity of the water. The conductivity values are then converted by meter scale calibration into equivalent concentrations of sea water. The meter is connected to the cell circuits by individual switches on each salinity cell. The specific electrical conductivity is measured by means of a bridge circuit which employs a special power-factor type meter. The meter measures the ratio of currents in the two separate arms of the bridge. One arm of the bridge is the dilute solution of sea water to be measured. The other arm of the bridge is an automatic temperature compensating resistor which has the same resistance-temperature characteristics as dilute solutions of sea water.

The power-factor type meter (fig. 15-26), employs a fixed coil and a movable coil. The movable coil consists of two windings, A and B, at right angles to each other. It is free to rotate within the fixed coil. The movable coil is energized from the secondary of power transformer, T1. Hence, the currents in winding A and B are in phase with each other and the circuits are resistive because of the series limiting resistor, R6. The fixed coil is energized from the ship's 115-volt 60-hertz power supply in series with the voltage dropping resistor, R12. The movable coil turns until its resultant field lines up with the field of the fixed coil. Therefore, the meter indication is directly dependent on the resultant field of the two movable windings, which in turn is dependent on the ratio of the currents in the two windings. The meter indication is independent of minor voltage and frequency changes of the power supply because there is no iron on the meter magnetic circuits and because the coil circuits are essentially resistive.

The currents in the two windings of the movable coil are proportional to the two loads in the bridge circuit. As previously stated, the load in one leg of the bridge (movable winding A) is the automatic temperature compensator C, located in the salinity cell, and in the other leg (movable winding B) is the resistance of the water being measured by the electrodes E. The meter reading which is determined by the ratio of the currents in the crossed windings, is therefore determined by the ratio of the cell resistance and the compensator resistance. At any given salinity and temperature there is only one possible meter reading. If the temperature is either raised or lowered from this point, the meter reading will remain unchanged because of the action of the compensator even though the water resistance may change appreciable. The temperature compensation occurs because any thermal change of the water being measured by the cell is immediately transfered to the automatic temperature compensator. The resistance of the compensator is inversely proportional to its temperature so that the thermal change transmitted to the compensator causes its resistance to change accordingly.

The resistance-temperature characteristics of the compensator are the same as those of dilute solutions of sea water. Therefore, the thermal change in the compensator, which is exactly the same as the thermal change of the sea water, causes sufficient resistive change in the compensator to compensate for the resistive change occuring in the cell. Although the absolute values of current in the windings have changed, their ratio has not changed and consequently the meter reading is unchanged. Because the temperature compensation is equally effective at all salinities, the only change that can vary the meter reading is a change in the current ratio caused by a change in salinity.

Salinity Cell Unit

A salinity cell plug-in unit (salinity module, fig. 15-26) is provided for each salinity cell to continuously monitor the purity of the water of the cell. The unit consists of an alarm circuit which includes a dual potentiometer R1, signal transformer T2, thyratron tube V1, flasher H2, red alarm light I2, and silence switch S2. A 3-position meter switch S1 is also provided on the unit. The alarm point value is predetermined and set. A high salinity condition is indicated initially by flashing of the red alarm light and sounding of the external audible alarms.

The alarm circuit can be traced from the salinity cell electrodes and compensator through the dual potentiometer R1 to the primary of the signal transformer T2, the secondary of which is connected to the control grid and cathode of the thyratron V1. The plate and cathode of V1 are connected across the 115-volt 60-hertz power supply in series with the flasher H2, and the red alarm light, I2.

There are two circuits from the secondary of power transformer T1 through the salinity cell, dual potentiometer R1, and primary of signal transformer T2. One circuit is through the electrodes, lower arm of R1, the primary of T2, the upper arm of R1, and resistor R6. The other circuit is through the compensator C, resistor R5, the upper arm of R1, the primary of T2, the lower arm of R1, and resistor R6. The conductance values of the salinity cell electrodes and compensator which are applied to the secondary of T1 and to the two arms of potentiometer, R1 determine the grid to cathode voltage of V1. The current flow through the two arms is in opposite directions or 180 degrees out of phase and the resultant voltage is impressed across the primary of T2.

For thyratron V1 to conduct, the voltage between the control grid and cathode (from the secondary of T2), must be in phase with the plate to cathode voltage.

When the salinity condition of the cell is higher than the alarm setting, the resistance across the two electrodes is decreased and more current flows through the lower arm of R1, the primary of T2, the upper arm of R1, and resistor R6. The resultant voltage is impressed across the grid and cathode of V1 through transformer T2. This voltage is of the proper phase to cause V1 to conduct during the half cycles when the grid and plate voltages of V1 are positive. The circuit is completed from one side of the line SB through the cathode and plate of V1, silence switch S2, rectifier CR4, flasher H2, rectifier CR3, red alarm light I2, to the other side of the line SBB.

The silencing switch S2, when placed in the SILENT (down) position, clears the external alarm circuit for other incoming alarms and causes the red alarm light to light steadily. When the high salinity condition is corrected, the red alarm light again flashes to remind the operator to place the switch S2 in the NORMAL (up) position to extinguish the red alarm light and clear the unit for future alarm signals.

The meter switch S1 is a 3-position, spring-loaded switch having a NORMAL (center) position, TEST position, and METER position. The meter switch S1, when placed in the TEST position, disconnects resistor R5B, in the salinity cell circuit resulting in an unbalanced condition which causes the cell to behave as though a high salinity condition exists. This action energizes the alarm circuit causing the red alarm light to flash and the alarm relay to sound the external alarm. The meter switch, S1, when placed in the METER position, connects the meter unit in the circuit of the associated salinity cell and a salinity reading is indicated on the meter.

Relay Unit

The relay module (fig. 15-26) consists of an alarm relay K2 and two 2-second delay flashers. For simplicity, only one flasher is shown. The flasher is used to delay the tripping time of the solenoid-operated valves. Normally, the current through the delay flasher contact circuit is not sufficient to open the flasher contacts. However, if terminal 5 of the relay unit is energized from an associated salinity cell, the flasher contact will open deenergizing control power relay K1-1 causing contacts K1-1 to open. This action deenergizes the valve control circuit causing the valve to actuate.

The rectifier CR2 allows a current to flow through the operating coil of alarm relay K2, from the plate of V1, through switch S2, in the NORMAL (up) position and back to the other side of the line SBB. Rectifier CR5, across the coil of K2, maintains the current flow through the coil during the nonconducting half cycles of V1. The contacts of relay K2 close to energize the external alarm circuit.

The silencing switch S2, when placed in the SILENT (down) position, opens the circuit to the audible alarm and connects the plate of V1 to one side of the alarm light through CR2. As long as the salinity is higher than the alarm setting, CR2 allows a current to flow directly through the red alarm light I2, which is lighted steadily. During this condition, CR3 prevents a large current flow through the heater of flasher, H2. When the salinity decreases to a value at which V1 ceases to conduct, the flasher heater voltage causes the red indicator light to flash as a reminder for the operator to place the silencing switch S2 in the NORMAL (up) position.

Normally, the current flows through the relay module from the line terminal, SBB, the bimetallic arm of the delay flasher, the coil of the power control relay K1-1, to the line terminal SB. This current maintains power relay K1-1, operated so that its contacts are closed. For simplicity, only one solenoid-operated valve is shown.

Valve Position and Meter Test Unit

The valve position and meter test module (fig. 15-26) is provided with a green valve position indicator lamp and a meter test switch. The dual purpose of the unit is to indicate when the control valve is in the NORMAL or ABNORMAL position and to provide a means of testing the meter unit.

When the solenoid trip valve is in the NORMAL position as shown, the green indicator lamp is illuminated steadily: when the control valve disk is in the ABNORMAL position the green alarm light flashes; and when the control valve is reset manually the green alarm light is again lighted steadily.

The meter test switch, when placed in the TEST position, connects the meter unit in a circuit simulating a known salinity condition (1.7 ppm) to check the calibration of the meter.

The valve position portion of the unit consists of the green indicator lamp I3 and the flasher H1, interconnected with the solenoid-operated valve. During normal operating conditions the solenoid is energized from line terminal SSB through the contacts of the power control relay K1-1, terminal 1 of the SPDT switch, S4 (on the control valve), to line terminal SB. The green indicator lamp I3 is illuminated steadily during this condition from line terminal SB, the contact arm of flasher H1, to line terminal SBB.

When an abnormal condition occurs, the power control relay K1-1 is deenergized and its contact opens the circuit to the solenoid coil which actuates switch S4. This action connects the heater and contact arm of flasher H1 from line terminal SB, through terminal 2 of switch S4, to line terminal SBB causing the green indicator light to flash.

The meter test portion of the unit consists of the meter test switch S3, resistor R10, and potentiometer R11. Normally, the meter unit is not connected to a salinity cell. The meter test switch S3 is a 2-position, spring-loaded rotary switch having a NORMAL (center) position and a TEST position. The rotary switch S3 when placed in the TEST position, connects the movable windings A and B of the power-factor-type meter in a circuit comprising resistor R10 and potentiometer R11, the resistances of which duplicates the resistances of the electrodes and compensator. There are two circuits through the movable windings. One circuit is from line terminal SB, the right arm of potentiometer R11, terminal 4 of switch S3, resistor R10 to line terminal SBB. The other circuit is from line terminal SB, the left arm of potentiometer R11, terminal 5 of switch S3, movable winding B, terminal 6 of switch S3, resistor R10, to line terminal SBB. With the meter test switch in the TEST position, the meter should read 1.7 ppm.

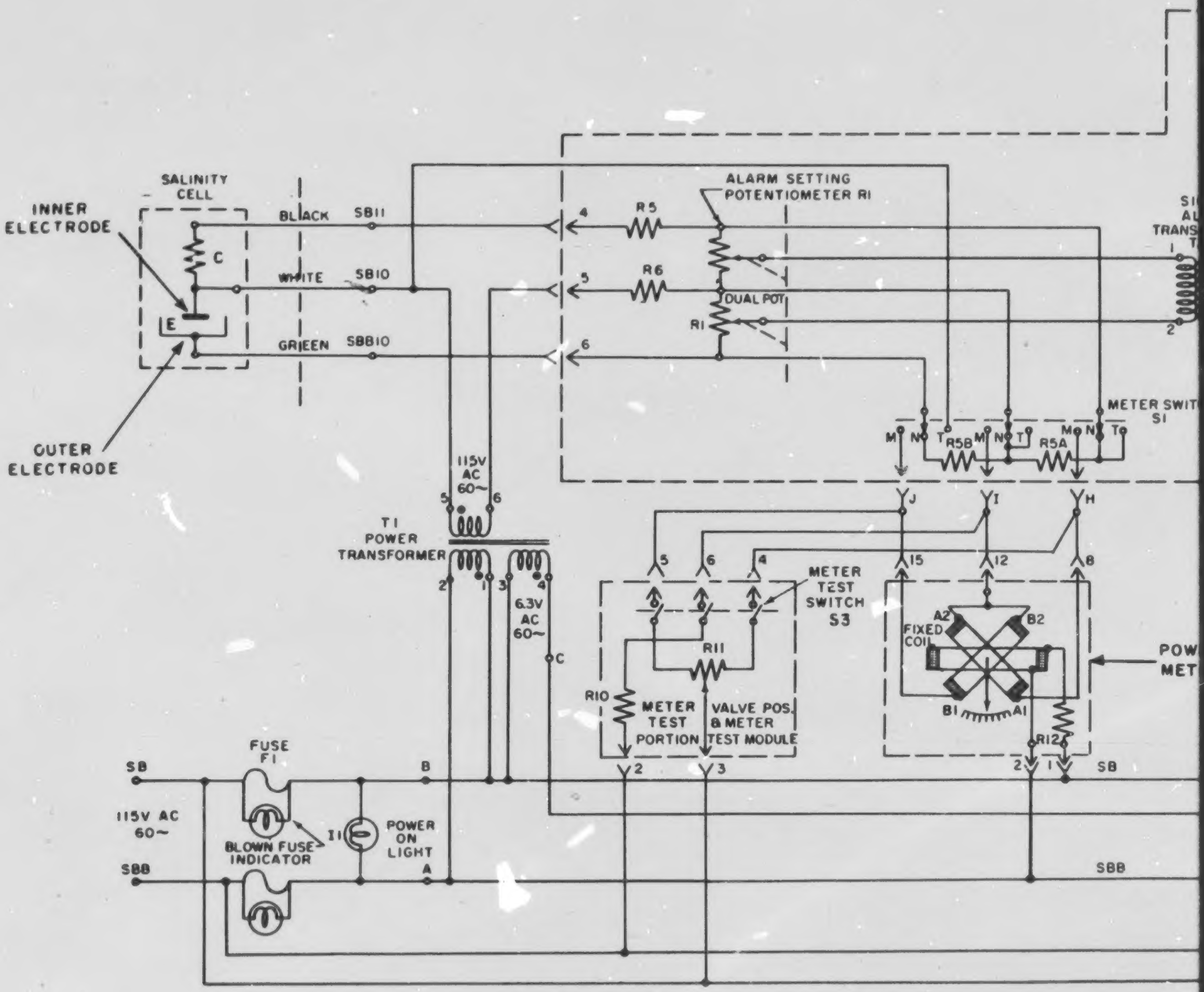
MAINTENANCE

The salinity cells should be inspected for mechanical damage and cleaned at least once a month. To remove a cell for inspection while the power is on and the system under pressure, proceed as follows: Loosen the setscrew in the packing nut (fig. 15-24) and slowly loosen the packing nut about one turn. Grasp the cable gland nut and pull the cell tube through the packing nut until a red groove on the cell tube can be seen, then close the gate valve. Remove the packing nut and cell tube from the nipple, and inspect the electrodes. Do not allow the electrodes to touch your body. If the electrodes show scale deposits, they must be cleaned.

To clean the electrodes, turn off the power and unscrew the outer electrode to permit cleaning the platinum surfaces. Use absorbent cotton and pure grain alcohol to clean the electrodes, then rinse them in distilled water. If this does not remove the deposits, soak the electrodes in a 50 percent solution of hydrochloric acid then rinse them thoroughly in distilled water. Do not use abrasives of any kind to clean the electrodes.

To reinstall the salinity cell, replace the outer electrode and push the cell tube through the packing nut until the red groove on the cell tube is just visible at the end of the packing nut. Screw the packing nut on the nipple using the cell tube as an alignment guide. When the packing nut compresses the packing against the outside wall of the cell tube, the gate valve may be opened cautiously. When the valve is open about one turn and full pressure applied to the electrodes, carefully tighten the packing nut to stop any small leaks. Do not overtighten the packing nut. When the small leaks are stopped, open the gate valve fully and push the cell tube inward until the setscrew can be set firmly in the groove on the cell tube.

Inspect the salinity indicator panel and its associated wiring frequently and remove any dust or dirt with clean rags or a vacuum cleaner. Check all electrical connections and mechanical fastenings for tightness. Replace any burned-out


SALINITY CELL
INNER ELECTRODE
OUTER ELECTRODE
C
E
BLACK
WHITE
GREEN
SB11
SB10
SBB10
4
5
6
R5
R6
ALARM SETTING POTENTIOMETER R1
DUAL POT
R1
METER SWIT
S1
M
N
T
R5B
R5A
J
I
H
15
12
8
115V AC 60~
T1 POWER TRANSFORMER
2
1
3
4
6.3V AC 60~
C
METER TEST SWITCH S3
R11
R10
METER TEST PORTION
VALVE POS. & METER TEST MODULE
2
3
A2
B2
FIXED COIL
B1
A1
R12
POW
MET
SB
SBB
115V AC 60~
FUSE F1
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I1
POWER ON LIGHT
B
A
TRANS

Fig

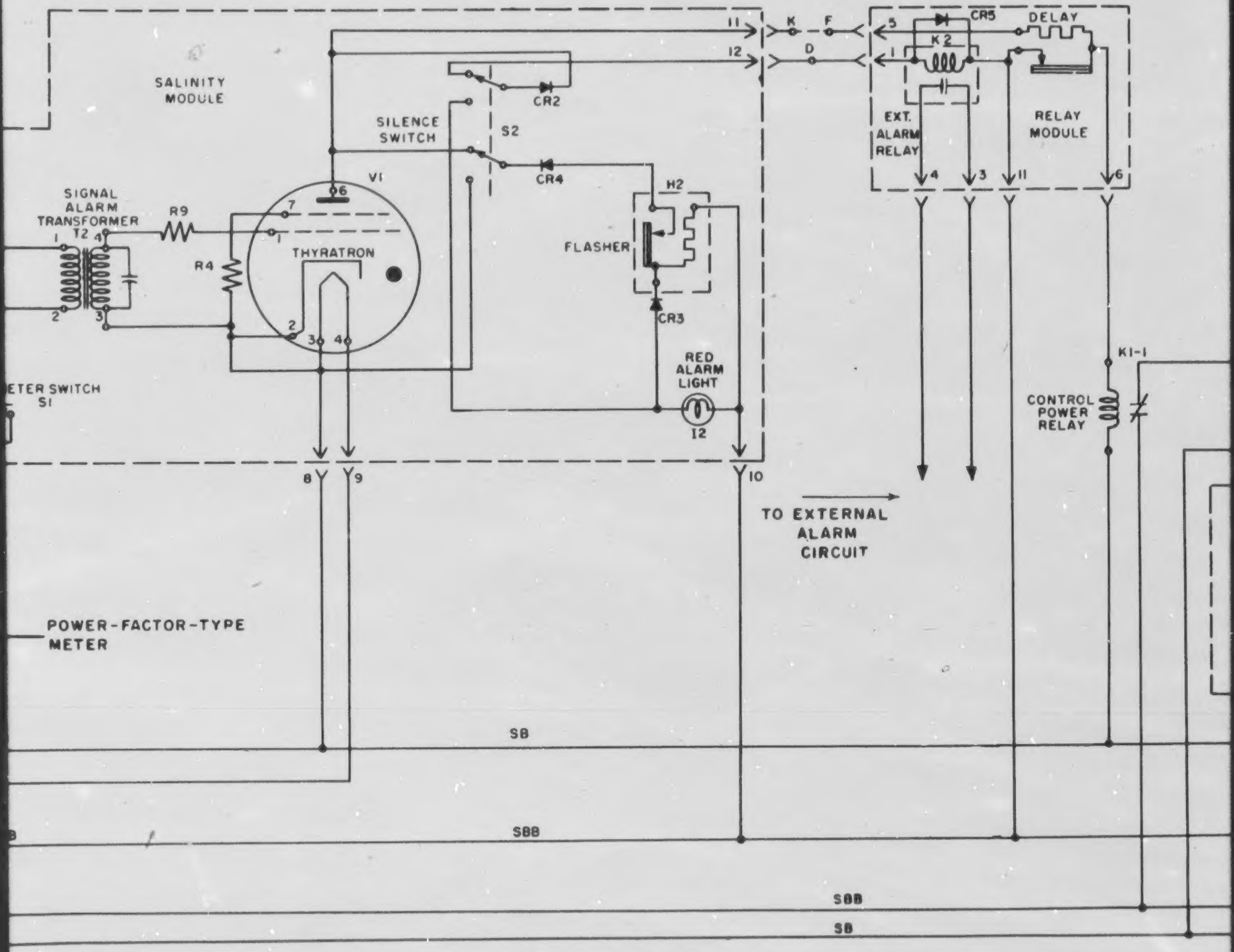
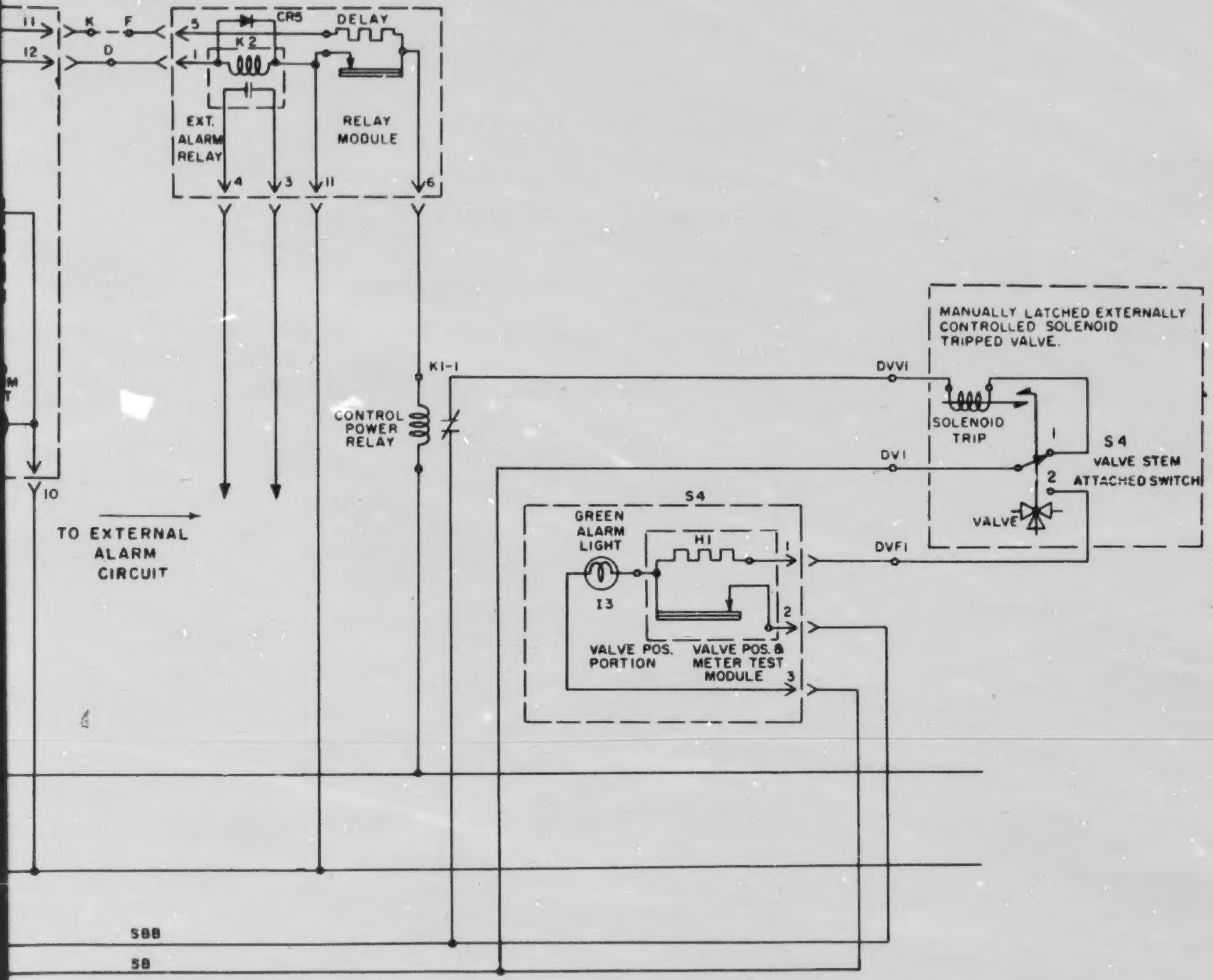

SALINITY MODULE
11
12
K
F
D
5
1
CR5
DELAY
K2
EXT. ALARM RELAY
RELAY MODULE
4
3
11
6
SILENCE SWITCH
S2
CR2
CR4
V1
6
7
1
THYRATRON
2
3
4
SIGNAL ALARM TRANSFORMER T2
1
2
3
4
R9
R4
H2
FLASHER
CR3
RED ALARM LIGHT
I2
ETER SWITCH S1
8
9
10
TO EXTERNAL ALARM CIRCUIT
K1-1
CONTROL POWER RELAY
POWER-FACTOR-TYPE METER
SB
SBB
SBB
SB

Figure 15-26.—Schematic diagram of salinity indicator system.


11
12
K
F
D
5
1
CR5
DELAY
K2
EXT. ALARM RELAY
RELAY MODULE
4
3
11
6
10
TO EXTERNAL ALARM CIRCUIT
K1-1
CONTROL POWER RELAY
DVV1
MANUALLY LATCHED EXTERNALLY CONTROLLED SOLENOID TRIPPED VALVE.
SOLENOID TRIP
1
S4
VALVE STEM ATTACHED SWITCH
DV1
2
VALVE
S4
GREEN ALARM LIGHT
I3
H1
1
DVF1
2
3
VALVE POS. PORTION
VALVE POS. & METER TEST MODULE
S8B
S8

indicator lights. When one bulb burns out in a dual bulb indicator light, replace both bulbs.

Turn off and tag the main supply switch for the system when working inside the panel. Removing the fuses on the panel will not cut off the power to the control relay circuits. Normally you will not be required to make extensive repairs to the modules. If a module fails, insert a spare of the same type in the panel and turn the faulty module in to a repair facility or the manufacturer as directed.

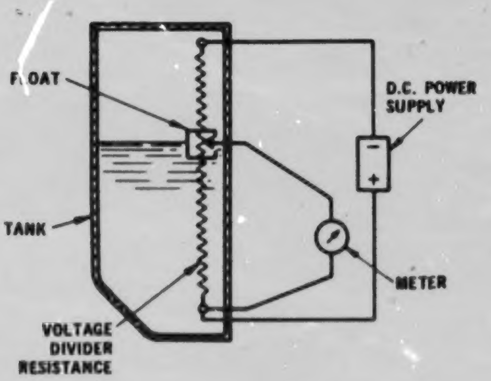
TANK LEVEL INDICATORS

The Navy is prohibited by Executive Order from polluting the sea with oil. To help prevent pollution, reliable gaging systems are used aboard ship to measure exactly the levels of oil tanks, especially fuel oil tanks that are compensated with sea water as the fuel oil is removed from the tanks. (Sea water is pumped into these tanks to keep them full and to maintain ship's center of gravity.) Sounding tubes and tapes are not practicable devices for measuring oil levels in compensated tanks. Neither are static-pressure sensing devices since they cannot distinguish between different fluids, as is the case in compensated fuel oil tanks. However, the IC/MF type of tank level indicator (built in accordance with MIL-L-23886) proved reliable and accurate enough to meet stringent requirements. This indicator distinguishes between two different fluids, such as sea water and fuel oil, by detecting variations in their specific gravities. Some models of the IC/MF indicator are also capable of sounding an alarm to warn of a high or low level in a fuel oil tank.

ELECTRO-MAGNETIC INDICATOR

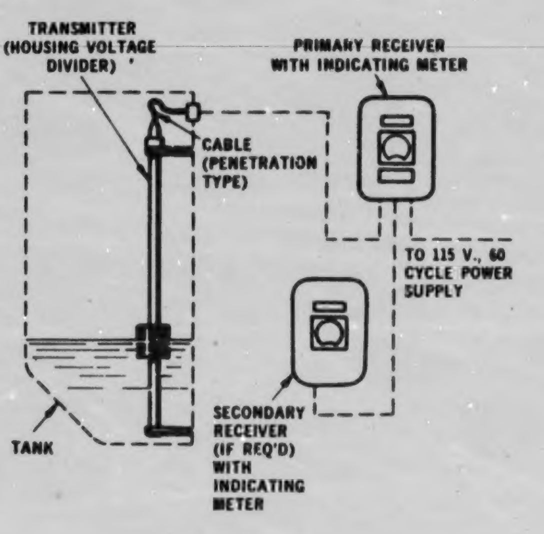
The Gems tank level gaging system functions electromechanically to provide a continuous remote meter reading of tank liquid level. A float moves up and down with liquid level to vary that portion of a voltage divider resistance across which a meter is connected, as in figure 15-27. Voltage drop read on the meter varies directly with this resistance portion according to Ohm's law (E = IR). The essential system is diagrammed in figure 15-28. Typical components are shown in figure 15-29.

The transmitter is the level detector unit mounted vertically within the tank by means of brackets or flanges. The magnet-equipped float moves along the transmitter subassembly to vary the voltage, which is indicated on receiver meter. Transmitters are used singly and connected together in multiples for deeper tanks. Transmitter models used in multiple installations are designed to function as a single long transmitter.



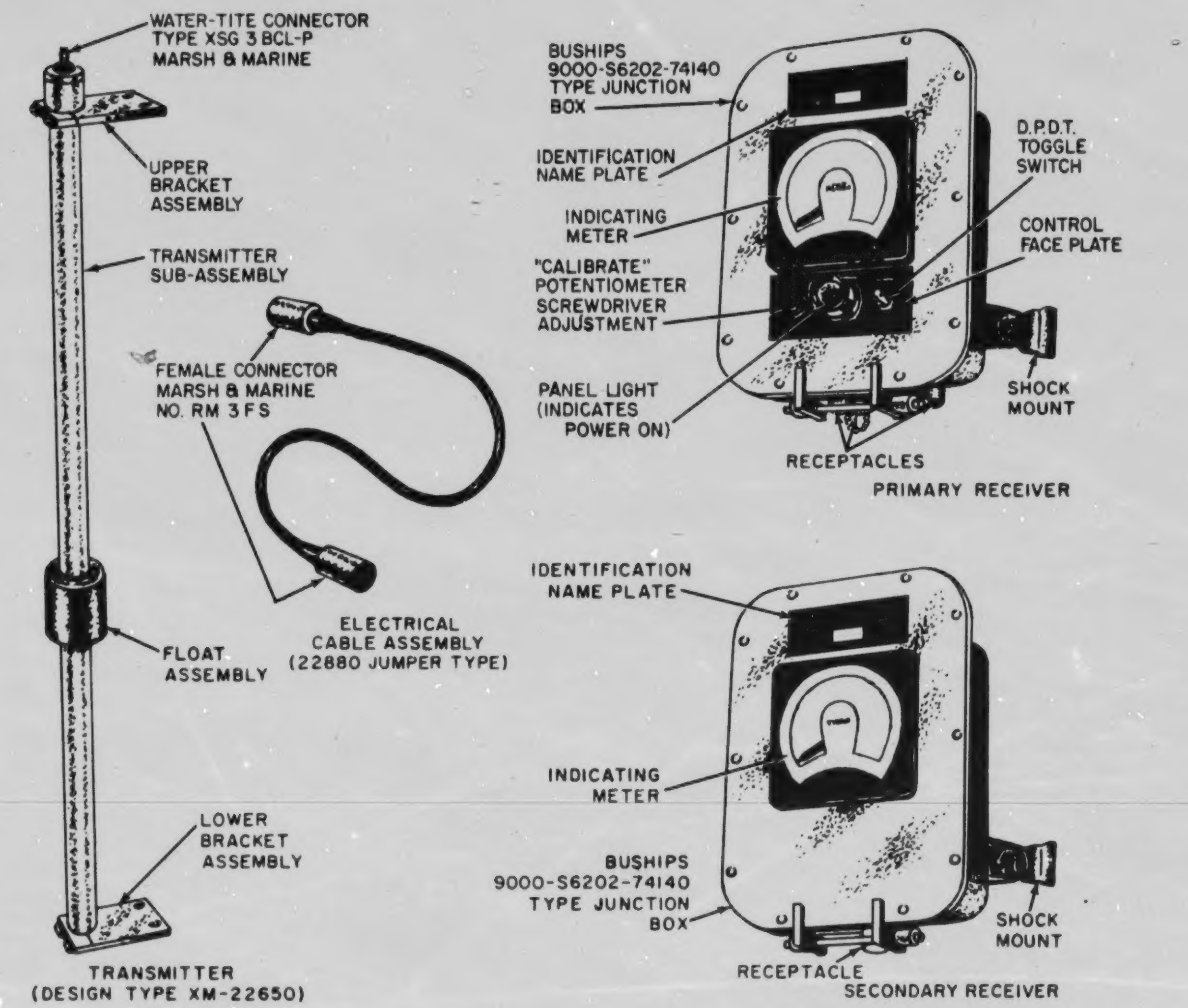
104.64

Figure 15-27.—Basic circuit for liquid level indicator.


TRANSMITTER (HOUSING VOLTAGE DIVIDER)
PRIMARY RECEIVER WITH INDICATING METER
CABLE (PENETRATION TYPE)
TO 115 V., 60 CYCLE POWER SUPPLY
SECONDARY RECEIVER (IF REQ'D) WITH INDICATING METER
TANK

104.65

Figure 15-28.—Diagram of a typical liquid level indicator system.


WATER-TITE CONNECTOR
TYPE XSG 3 BCL-P
MARSH & MARINE
UPPER
BRACKET
ASSEMBLY
TRANSMITTER
SUB-ASSEMBLY
FEMALE CONNECTOR
MARSH & MARINE
NO. RM 3 F S
ELECTRICAL
CABLE ASSEMBLY
(22880 JUMPER TYPE)
FLOAT
ASSEMBLY
LOWER
BRACKET
ASSEMBLY
TRANSMITTER
(DESIGN TYPE XM-22650)
BUSHIPS
9000-S6202-74140
TYPE JUNCTION
BOX
IDENTIFICATION
NAME PLATE
INDICATING
METER
"CALIBRATE"
POTENTIOMETER
SCREWDRIVER
ADJUSTMENT
PANEL LIGHT
(INDICATES
POWER ON)
D.P.D.T.
TOGGLE
SWITCH
CONTROL
FACE PLATE
SHOCK
MOUNT
RECEPTACLES
PRIMARY RECEIVER
IDENTIFICATION
NAME PLATE
INDICATING
METER
BUSHIPS
9000-S6202-74140
TYPE JUNCTION
BOX
SHOCK
MOUNT
RECEPTACLE
SECONDARY RECEIVER

104.66

Figure 15-29.—Standard components typical of tank level gaging system.

Liquid levels are continuously indicated from a predetermined point above tank bottom to the top of the tank, depending on the transmitter model.

A continuous indication of liquid level, as detected by the transmitter, is read directly from the meter on the primary receiver. In addition to the indicating meter, the d-c power supply and all system controls are housed in a standard junction box. The primary unit is located remotely from, and is cable-connected to, the transmitter. One or more remotely located secondary receivers and recorders can be connected to this system. Each secondary receiver houses a level indicating meter only.

AIR FLOW INDICATOR AND ALARM PANEL (TYPE IC/ASE)

The airflow indicator and alarm panel (circuit HF) is a remote panel installed in each compartment that needs a constant supply of fresh air. The meter can indicate a flow of air not exceeding 1,000 feet per minute (fpm). An alarm sounds when the air flow from the exhaust ventilation decreases to a predetermined level which is set by a second pointer on the meter face.

Under normal operating conditions, the sensor detects the air flow by rotation of its vanes. An interruption of contacts as the vanes turn produces the pulses that operate the meter.

The indicator is an electronic signal unit type IC/E102, a modification of the unit shown in figure 7-6. It serves as the alarm portion of the system and can be used with remote alarm units. A 12-volt battery inside the enclosure supplies power to the entire unit during normal and emergency operations.

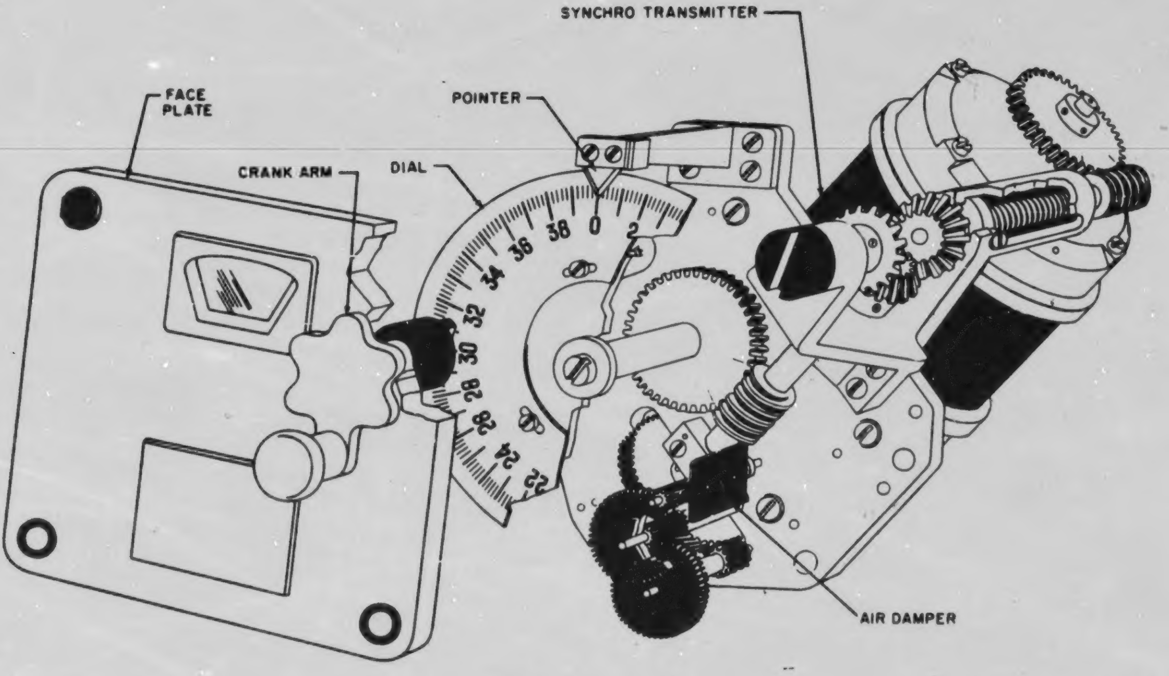
DUMMY LOG

Due to low speed inaccuracies in the underwater log and the desirability to simulate ship's movement through the water in order to train personnel, align equipment, or get underway without the use of the underwater log system, the dummy log system circuit 4Y was developed. This system is found on the older class ships which do not have an underwater log system with a dummy log incorporated into it.

SPEED TRANSMITTER

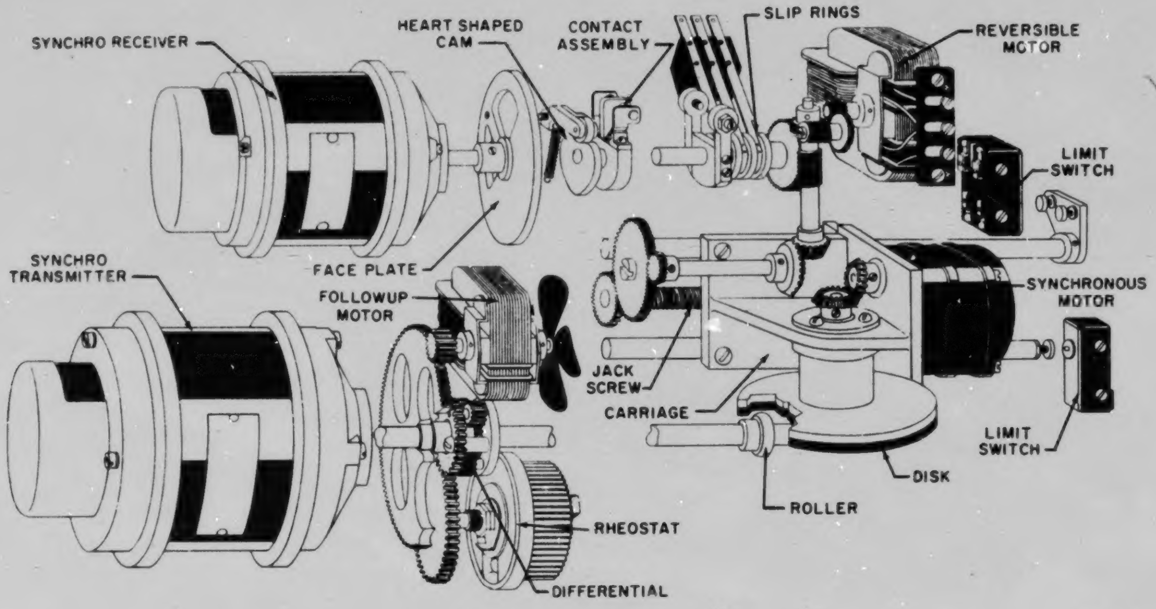
The speed transmitter (fig. 15-30) is generally located in the main engineroom control, while the distance transmitter is usually located in the forward IC room.

The first component of the system, the speed transmitter, consists of a synchro transmitter, a dial for indication, an air damper, and a handle (crank). The operator turns the handle positioning the synchro transmitter and the dial through required gearing. The dial is graduated in steps of 0.2 knots, from 0 to 40 knots. The air damper functions to reduce the rate of change to a maximum of 8 knots change in one minute. The signal representing an angular displacement is sent to



140.110

Figure 15-30.—Dummy log speed transmitter.



140.111

Figure 15-31. —Dummy log distance transmitter.

the IC ACO switchboard for further distribution and is also sent to the dummy log distance transmitter.

DISTANCE TRANSMITTER

The distance transmitter (fig. 15-31) functions as a converter taking in the angular displacement of the speed transmitter and presenting it as rotary motion to represent distance traveled in circuitry and on counters. The unit consists of four subassemblies mounted on one base plate: the synchro receiver assembly, the reversible motor assembly, the synchronous motor assembly, and the synchro transmitter assembly.

The synchro receiver takes in the angular displacement signal and turns its face plate in correspondence. As it moves, the face plate takes the heart-shaped cam roller out of the "V" and around the surface of the cam of the extent of the input angular displacement signal.

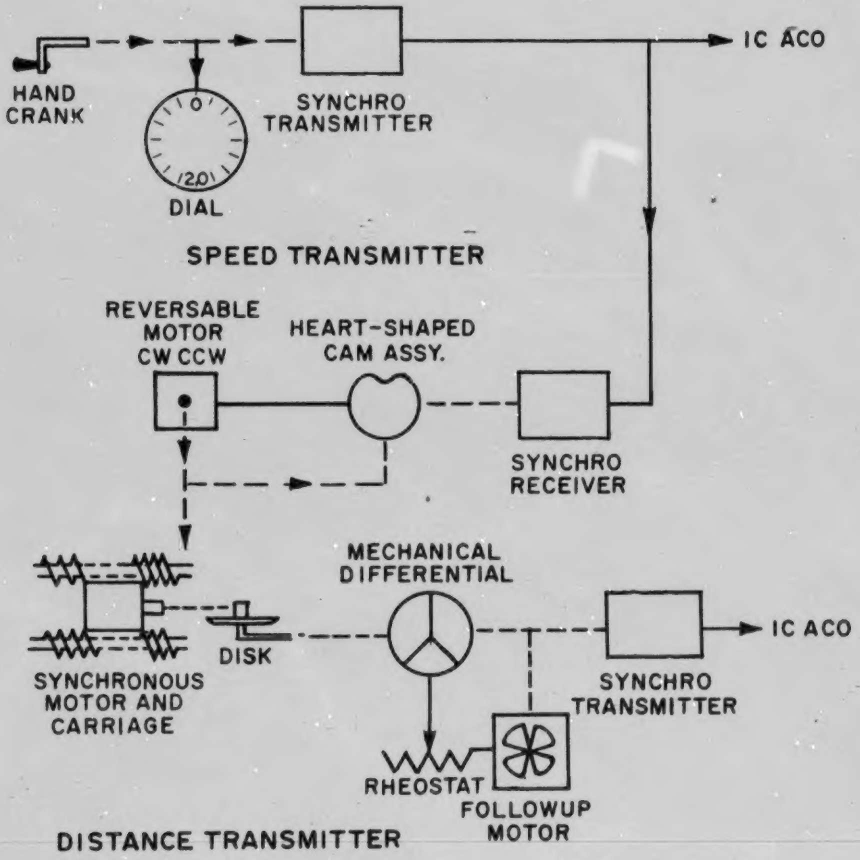
The roller, on leaving the "V," is followed by the cam and its stop support which are free on their shaft. Movement of the heart-shaped cam is, however, restricted by the contact assembly located above the stop.

The stop in restriction closes contacts which, through the slip-ring assembly, energize the reversible motor in a direction to align the cam, stop, and contact assembly with the roller and synchro receiver. The reversible motor operates counterclockwise on speed increases, and clockwise on speed decreases.

When back in alignment, with no speed change, the roller is again in the "V" and the reversible motor contacts are again open, causing the motor to stop. (The speed of response of the heart-shaped cam is such as to require the 8 knots per minute change limitation mentioned earlier.)

While turning the heart-shaped cam, the reversible motor also positions gearing and a jack shaft so as to move the synchronous motor carriage assembly. This assembly contains a roller disk and roller located on its underside. The synchronous (capacitor-start) motor rotates the disk at a constant 60 rpm. The carriage positions the disk face atop the roller so that at zero speed the roller is centered, and at higher speeds the roller is at varying distances about the face of the disk.

Friction between the disk and the roller causes the roller to rotate (at all but center disk


IC ACO
HAND CRANK
SYNCHRO TRANSMITTER
0
120
DIAL
SPEED TRANSMITTER
REVERSABLE MOTOR CW CCW
HEART-SHAPED CAM ASSY.
SYNCHRO RECEIVER
MECHANICAL DIFFERENTIAL
IC ACO
DISK
SYNCHRONOUS MOTOR AND CARRIAGE
SYNCHRO TRANSMITTER
RHEOSTAT
FOLLOWUP MOTOR
DISTANCE TRANSMITTER

140.112

Figure 15-32.—Dummy log circuit.

position). As the center of the disk is moved further from the roller, the latter rotates at increasing speeds (240 rpm at 40 knots).

The roller shaft speed is a direct representation of distance, as it is rotary motion corresponding to the speed angular displacement input. The roller shaft (driven only by friction) is ill-equipped to continually drive a synchro transmitter; therefore a differential and followup subassembly is installed prior to the transmitter.

The roller turns one side of a spur gear mechanical differential. The difference between roller speed and the other differential side is used to position a rheostat which is inserted in the circuit of a followup motor. The followup motor turns, keeping the second side of the differential rotating at a speed corresponding with the roller side, and simultaneously rotating the rotor of the distance transmitter.

Two sets of limit switches are employed in the unit; a single switch to deenergize the synchronous motor when the roller is at or near center disk position and a double switch to deenergize the reversible motor when the disk is at its farthest point of travel (roller near edge).

OPERATION

The main points in the operation of the dummy log are shown by figure 15-32. A summary of the operation follows: The operator in main control turns the handle on the speed synchro transmitter so as to position his dial and transmitter. The signal is passed on to the distance transmitter where the input receiver positions its face plate, removing the roller from the "V" of the heart-shaped cam.

In attempting to follow the roller, the cam and its stop actuate contacts causing the reversible motor to drive, repositioning the cam and stop, and positioning the synchronous motor carriage subassembly. The position of the rotation of the synchronous motor disk causes the roller (below the disk) to rotate at a speed corresponding to the input indication. Through differential action, a rheostat, and a followup motor, the roller rotates a synchro transmitter to indicate with rotary motion, ship's distance. Indication of speed is now available as angular displacement, ship's distance traveled as rotary motion.

CHAPTER 16

PLOTTING SYSTEMS

The NC-2 plotting system has replaced the Arma Dead Reckoning Analyzer-Dead Reckoning Tracer (DRA-DRT) combination as the primary ASW, surface, and radar plotter. The takeover is not yet complete, however, and some ships have both an NC-2 system and at least one DRA-DRT system. In these ships the NC-2 is used with ASW, surface, and radar inputs; the DRA-DRT is used as a standby system and for secondary duties, such as navigation and drills.

The objective of this chapter is to describe the major components and operating principles of the plotting systems named above. The information will help you maintain the plotting equipment or enable you to communicate with those assigned to maintain it. Do not try to repair this equipment without referring continually to the technical manuals furnished by the manufacturer's of the equipment.

DEAD RECKONING EQUIPMENT

Dead reckoning equipment (DRE) comprises a dead reckoning analyzer and a dead reckoning tracer. A dead reckoning indicator is included with the tracking mechanism in the dead reckoning tracer. A block diagram of the dead reckoning system is illustrated in figure 16-1.

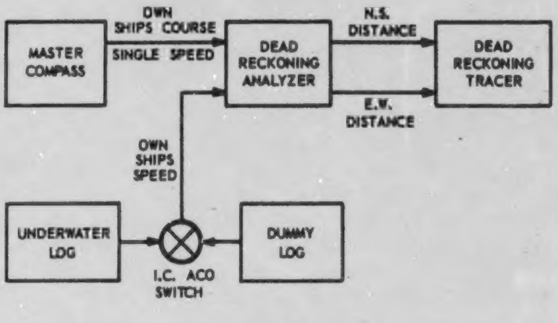
The dead reckoning system, circuit TL, provides a means of indicating the ship's position in latitude and longitude on an appropriate chart by means of a range-bearing projector (plotting light), or on mechanical dials. It may also record graphically on an appropriate chart, the ship's travel relative to a fixed starting point. When properly set at the starting point, the mechanisms of the dead reckoning equipment indicate continuously the ship's latitude and longitude by computing mechanically the distance traveled by the ship and the ship's course. The distance traveled is computed from the input received from the underwater log; the course input is received from the master gyrocompass.

DEAD RECKONING ANALYZER

The dead reckoning analyzer (DRA) receives the ship's distance input from the underwater log system, and the ship's course input from the master-compass single speed transmitter. These two inputs are combined to determine and indicate the total distance and also the overall distances in a north-south and an east-west direction traveled by the ship from any given starting point. This analyzer unit consists of (1) a distance converter; (2) roller carriages; and (3) a ship's course crank arm mechanism enclosed in a metal case provided with a hinged cover (fig. 16-2). The east miles counter, north miles counter, total miles counter, and course dial are visible through a window in this cover. The dead reckoning analyzer is designed for bulkhead mounting and is located in the chart house, or on occasion, in CIC.

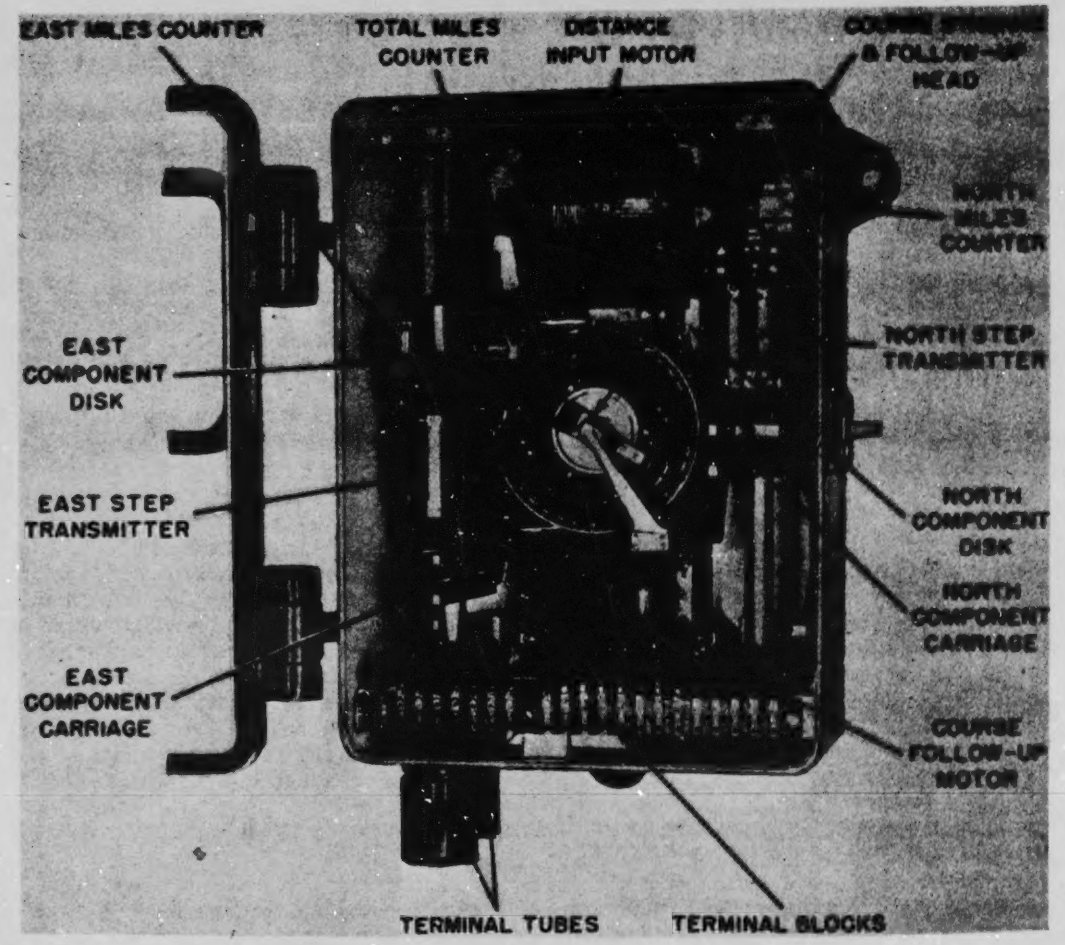
DISTANCE CONVERTER

The distance converter is illustrated in the diagram of the DRA in figure 16-3. It includes



40.56

Figure 16-1.—Dead reckoning system, block diagram.


EAST MILES COUNTER
TOTAL MILES COUNTER
DISTANCE INPUT MOTOR
COURSE SYNCHRO & FOLLOW-UP HEAD
NORTH MILES COUNTER
NORTH STEP TRANSMITTER
EAST COMPONENT DISK
EAST STEP TRANSMITTER
NORTH COMPONENT DISK
NORTH COMPONENT CARRIAGE
EAST COMPONENT CARRIAGE
COURSE FOLLOW-UP MOTOR
TERMINAL TUBES
TERMINAL BLOCKS

40.57

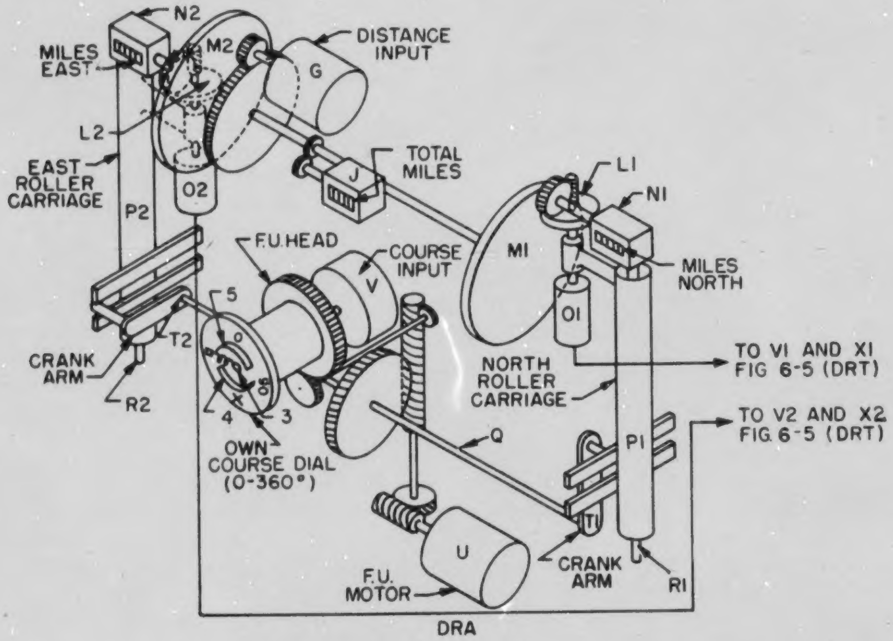
Figure 16-2. — Dead reckoning analyzer.

a distance input differential synchro receiver, G, which is electrically driven by the underwater log distance transmitter. The differential receiver acts as an ordinary receiver and turns at the rate of 360 revolutions per mile.

The distance input synchro, G, is geared directly to the shaft on which the two disks, M1 and M2, are mounted; therefore, their rotation is directly proportional to the distance traveled. It is from the rotation of these disks that the north and east components of the ship's travel are taken. Thus, they are called the north and east component disks. The counter, J, which is geared to the shaft that drives the disks, indicates the total miles traveled by the ship.

ROLLER CARRIAGES

The roller carriages, P1 and P2 (fig. 16-3), are mounted on guide rods R1 and R2. The ends of the roller carriages are provided with a set of guide rollers (not shown) to ensure free motion of the carriages along the guide rods. The carriages are positioned along the guide rods by a crank arm mechanism that is controlled by the signal from the master compass.


N2
MILES EAST
M2
DISTANCE INPUT
G
L2
EAST ROLLER CARRIAGE
O2
P2
TOTAL MILES
J
L1
N1
MILES NORTH
M1
F.U. HEAD
COURSE INPUT
V
5
T2
CRANK ARM
R2
O1
NORTH ROLLER CARRIAGE
TO V1 AND X1 FIG 6-5 (DRT)
TO V2 AND X2 FIG 6-5 (DRT)
4
3
OWN COURSE DIAL (0-360°)
Q
P1
T1
CRANK ARM
R1
F.U. MOTOR
U
DRA

40.58

Figure 16-3. — DRA gearing diagram.

The distance rollers, L1 and L2, are mounted on the north and east roller carriages respectively, and bear against the corresponding disks, M1 and M2. These rollers are positioned so that their turns are proportional to the north-south and east-west components respectively of the ship's distance.

When a carriage is positioned so that its distance roller is near the edge of its component disk, the roller is driven a maximum number of revolutions by each revolution of the disk. As the distance roller is moved toward the center of the disk, it is driven at a slower rate. When the roller is at the center of the disk, it is stationary, and no motion is transmitted to its shaft. Conversely, if the distance roller passes the center of the disk, it will be driven in the opposite direction.

The crank arm mechanism positions the carriages so that on a north-south or an east-west course, one of the distance rollers is at the edge of, and the other distance roller is at the center of, its component disk. Thus, on a north or south course, the north distance roller is driven at a maximum rate, and the east distance roller is stationary. Conversely, on an east or west course, the east distance roller is driven at a maximum rate, and the north distance roller is stationary. On an intermediate course, both distance rollers are driven, the respective rates of rotation being proportional to the north-south and the east-west components of the ship's course.

The distance rollers, L1 and L2, drive the north counter, N1, and the east counter, N2, through worm gears to indicate the ship's travel in total miles north and in total miles east. Motions to the north or to the east are assumed as positive and cause the counters to indicate increasing readings. Conversely, motions to the south or to the west are assumed as negative and cause the counters to indicate decreasing readings.

The DC step-by-step transmitters, 01 and 02, are mounted on the shafts of the distance rollers, L1 and L2, respectively. These transmitters control the step-by-step receivers, V1 and V2, respectively, in the dead reckoning indicator and also the receivers, X1 and X2, in the dead reckoning tracer. The rotation of these receivers is therefore directly proportional to the north or east components of the ship's travel and can be used to operate the desired indicating and recording mechanisms in the dead reckoning tracer.

SHIP'S COURSE CRANK ARM MECHANISM

The ship's course crank arm mechanism (fig. 16-3) includes a course input synchro receiver, V, that is electrically driven by the master-compass transmitter. This receiver cannot furnish sufficient power to operate the crank arm mechanism; hence, a followup system is required. The synchro receiver controls the followup motor, U. The motor, through a gear train, moves a compass dial, X, and the crank arms, T1 and T2, that control the positions of the north and east roller carriages, P1 and P2, respectively.

The crank arms are mounted at right angles to each other on a common shaft (fig. 16-3). The crank pins engage slots in the roller carriages. These slots are at right angles to the guide rods, R1 and R2. When either crank arm is at right angles to its associated guide rod, the throw of the crank arms positions its speed roller at the center of the associated disks, and no motion is transmitted to it. Conversely, when either crank arm is parallel to its guide rod, the throw of the crank arms positions its speed roller at the edge of the associated disk, and maximum motion is transmitted to it.

The ship's course dial, X, the split ring segments, 4 and 5, and the crankshaft, Q, are geared to the followup motor, U, and rotate with it when the motor is energized. The rotor of the course synchro receiver will not change its position with respect to its stator except when the course indication from the master compass changes.

Contact brush 3 is mounted on the shaft of the course synchro receiver, which extends through the ship's course dial mounting and can rotate freely within it. This brush can come into contact with either of the two segments of the split ring, which are connected to the follow-up motor. This action will cause the followup motor to run either in a clockwise or in a counterclockwise direction, depending on which segment is contacted by the brush. Normally, the brush is in the dead space between the rings and does not touch either ring, and the followup motor does not operate.

When the rotor moves in response to a change in course, contact is made on one of the split-ring segments. The followup motor then moves the crank arms, the ship's course dial, and the split ring assembly in a direction that brings the split ring into synchronism with the brush. In this position the course dial indicates the true heading, and the roller carriages are correctly positioned by the crank arms to provide the proper north and east components as the output of the analyzer. When there is no longer a change in compass course, the synchro receiver rotor stops turning but the segments continue to turn until the brush is in the dead space between the segments, and the followup motor stops.

DEAD RECKONING INDICATOR

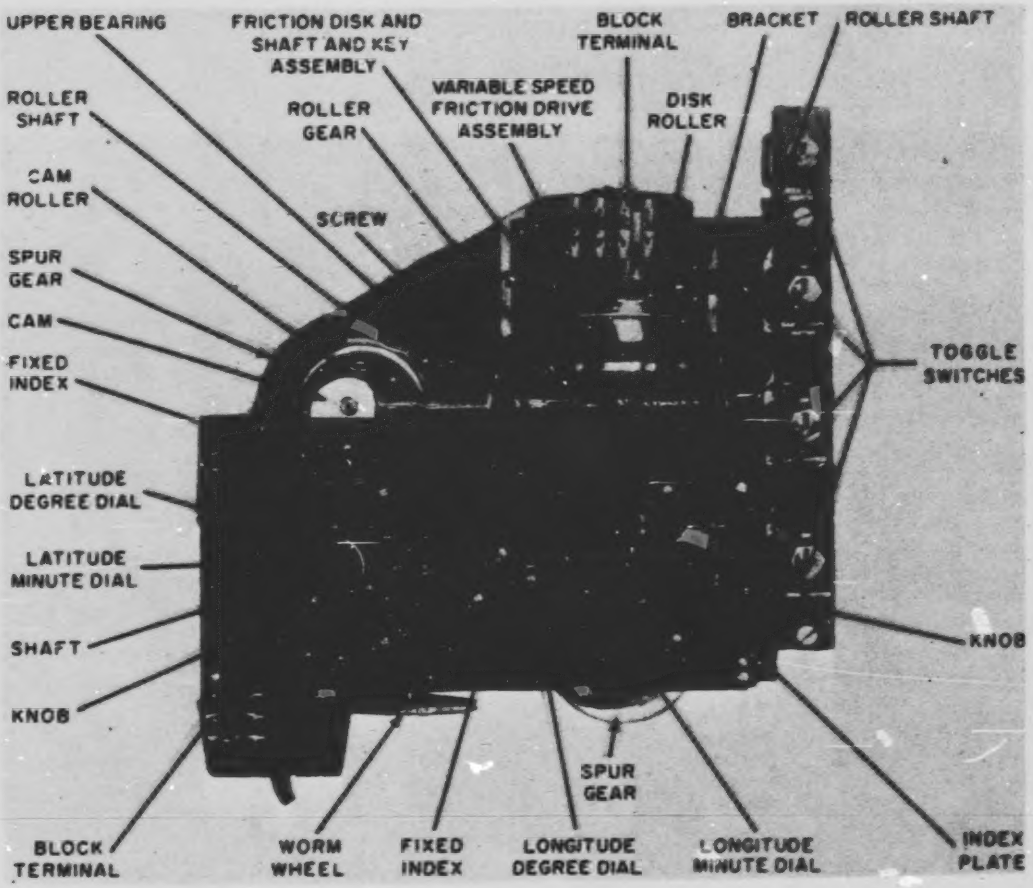
The dead reckoning indicator (DRI) is contained in the tracking mechanism of the dead reckoning tracer. It consists of a dial unit assembly that includes the latitude motor and dials, longitude motor and dials, and latitude correction mechanism (fig. 16-4). The latitude and longitude dial assemblies each consist of two concentric dials. The outer latitude and longitude dials are graduated in degrees and the inner latitude and longitude dials are graduated in minutes.

A schematic diagram of the DRI is illustrated in the schematic for the DRT in figure 16-5. The output from the north step transmitter, 01, in the DRA drives the latitude step receiver, V1, that is geared to the latitude dials. Similarly, the output of the east step transmitter, 02, drives the longitude step receiver, V2, that is geared indirectly to the longitude dials through a speed correction mechanism.

The latitude dials, F1, are geared directly to the latitude step receiver. There is a fixed relation between a degree of latitude and a degree of displacement of the receiver rotor. (One degree of latitude is approximately equal to 60 nautical miles anywhere on the earth's surface.) A reversing latitude and longitude indicator switch, T, is provided for reversing the direction of rotation of the latitude dials when the equator is crossed.

LATITUDE CORRECTION MECHANISM

The longitude dials cannot be geared directly to the longitude step receiver because the relation between a degree of longitude and a degree


UPPER BEARING
FRICTION DISK AND SHAFT AND KEY ASSEMBLY
BLOCK TERMINAL
BRACKET
ROLLER SHAFT
ROLLER SHAFT
ROLLER GEAR
VARIABLE SPEED FRICTION DRIVE ASSEMBLY
DISK ROLLER
CAM ROLLER
SCREW
SPUR GEAR
CAM
FIXED INDEX
TOGGLE SWITCHES
LATITUDE DEGREE DIAL
LATITUDE MINUTE DIAL
SHAFT
KNOB
KNOB
SPUR GEAR
BLOCK TERMINAL
WORM WHEEL
FIXED INDEX
LONGITUDE DEGREE DIAL
LONGITUDE MINUTE DIAL
INDEX PLATE

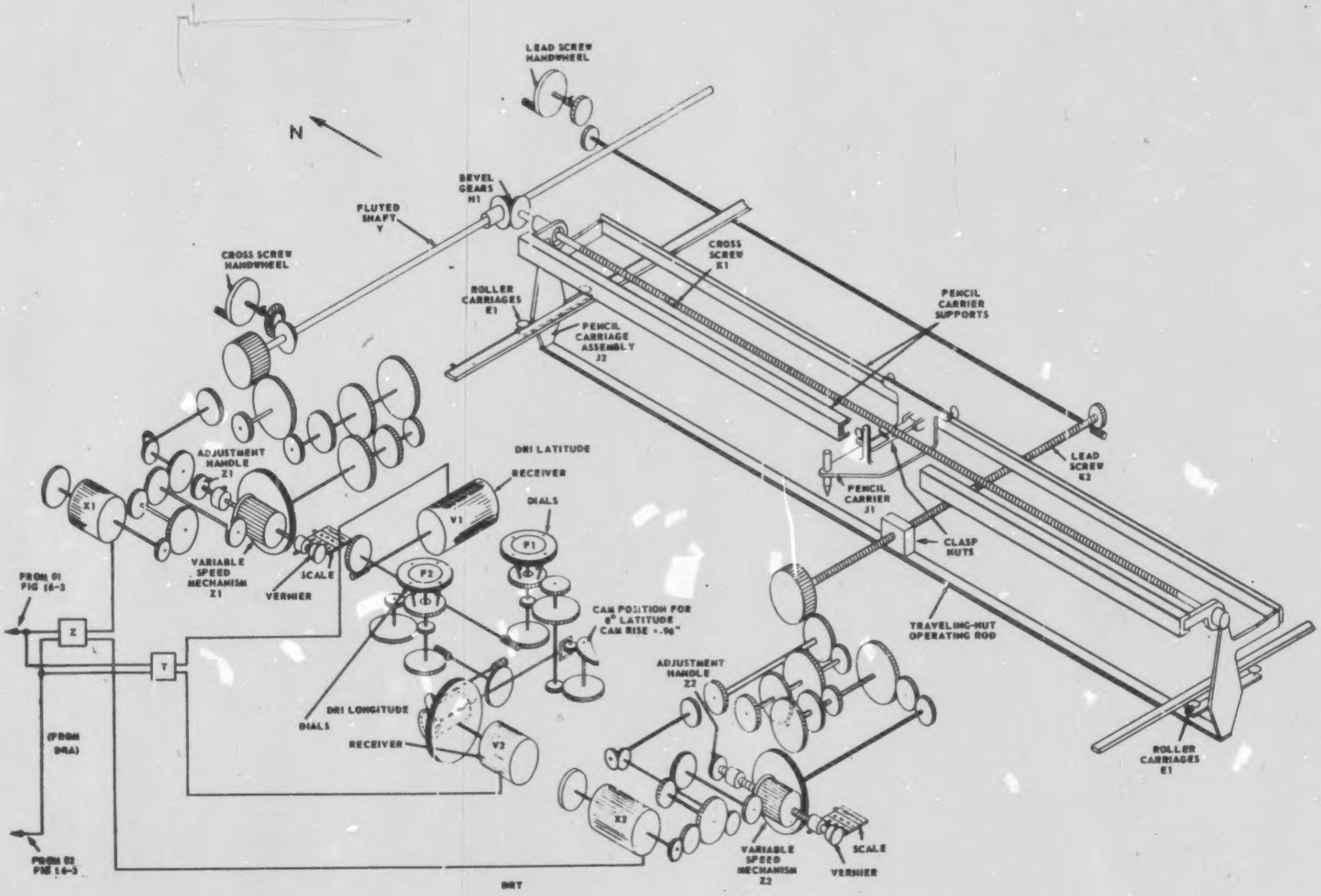
40.59

Figure 16-4. — Dead reckoning indicator.

of displacement of the longitude step receiver, V2, varies with the latitude. The latitude correction mechanism (fig. 16-5) is introduced between the longitude receiver, V2, and the longitude dials, F2, in order to adjust the number of miles east-west per degree of longitude in accordance with the latitude of the ship. This mechanism consists of a friction disk and roller assembly. The disk is attached to the shaft of the longitude motor, V2, and drives the friction roller at a speed proportional to the radial distance to the center of the disk. A cam follower is driven by a cam geared to the latitude degree dial and controls the position of the friction roller to provide the proper speed ratio for the given latitude. Thus, at 60° latitude, where 1° of longitude equals approximately 30 miles, the cam holds the friction roller in a position so that it turns twice as fast as it would turn at the equator. A spur gear meshes with a gear on the friction roller that drives the longitude dials, F2. The reversing switch, T, also provides for changing the direction of rotation of the longitude dials when the 0° or 180° meridian of longitude is crossed.

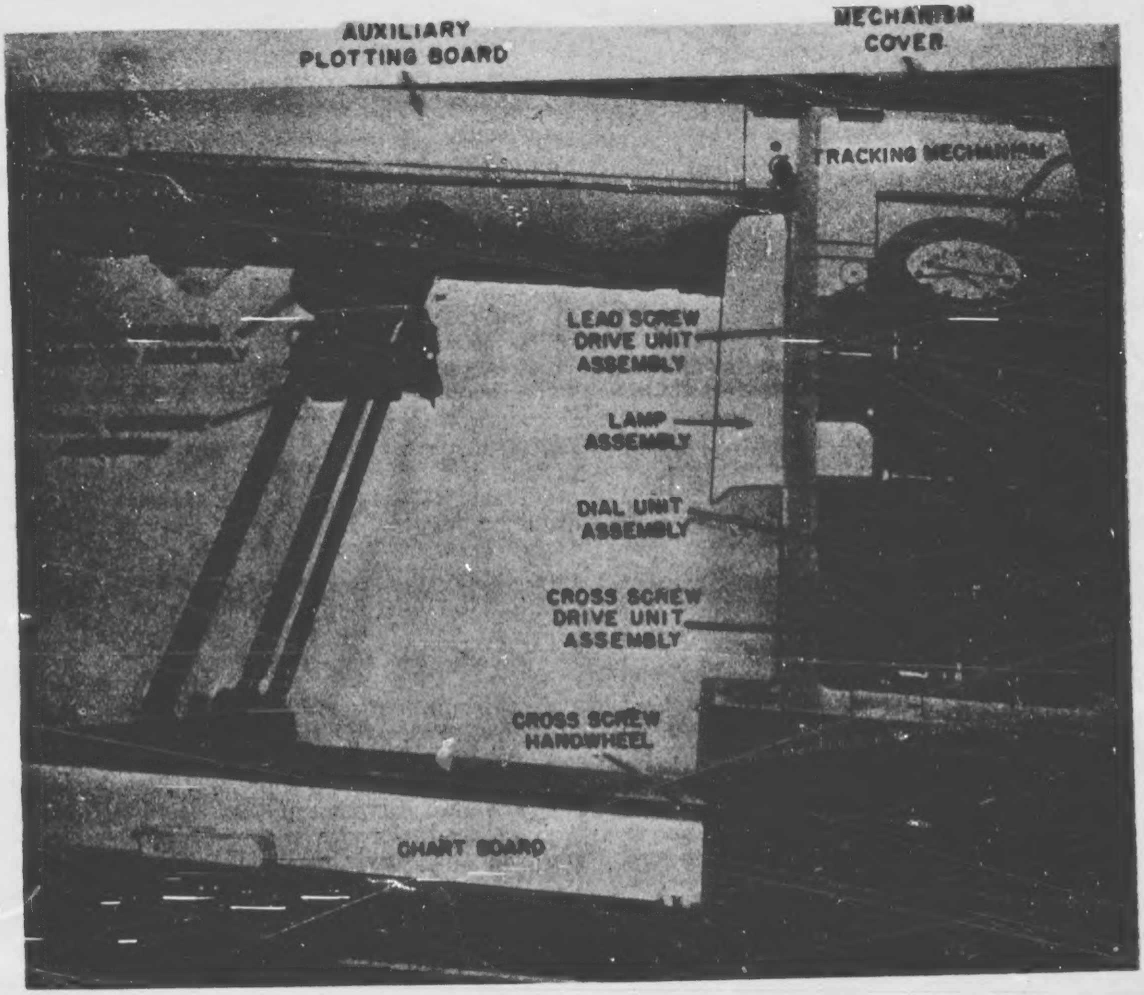
DEAD RECKONING TRACER

The dead reckoning tracer (DRT) consists of (1) a tracking mechanism; (2) a chart board


LEAD SCREW HANDWHEEL
N
BEVEL GEARS H1
FLUTED SHAFT Y
CROSS SCREW HANDWHEEL
CROSS SCREW K1
ROLLER CARRIAGES E1
PENCIL CARRIAGE ASSEMBLY J2
PENCIL CARRIER SUPPORTS
LEAD SCREW K2
PENCIL CARRIER J1
CLASP NUTS
TRAVELING-NUT OPERATING ROD
ROLLER CARRIAGES E1
ADJUSTMENT HANDLE Z1
X1
VARIABLE SPEED MECHANISM Z1
SCALE
VERNIER
DRI LATITUDE
RECEIVER
V1
DIALS
F1
F2
CAM POSITION FOR 0° LATITUDE CAM RISE =.96"
DRI LONGITUDE
DIALS
RECEIVER
V2
ADJUSTMENT HANDLE Z2
X2
VARIABLE SPEED MECHANISM Z2
SCALE
VERNIER
FROM 01 FIG 16-3
Z
T
(FROM DRA)
FROM 02 FIG 16-3
DRT

40.60

Figure 16-5. — DRT gearing diagram.


AUXILIARY PLOTTING BOARD
MECHANISM COVER
TRACKING MECHANISM
LEAD SCREW DRIVE UNIT ASSEMBLY
LAMP ASSEMBLY
DIAL UNIT ASSEMBLY
CROSS SCREW DRIVE UNIT ASSEMBLY
CROSS SCREW HANDWHEEL
CHART BOARD

40.61

Figure 16-6. — Dead reckoning tracer with auxiliary plotting board.

that includes the pencil carrier assembly; and (3) an auxiliary plotting board (fig. 16-6). The auxiliary plotting board is included with the DRT for plotting ranges and bearings of contacts that are being tracked, and for plotting own ship's course. The DRT is housed in a metal case designed for horizontal mounting on a table or cabinet and is located in the combat information center.

A schematic diagram of the DRT is illustrated in figure 16-5. The DRT, in addition to the DRI, receives from the DRA the outputs of the north and the east step transmitters, 01 and 02, that actuate the step receivers, X1 and X2, respectively. These step receivers in turn operate the mechanisms that drive the pencil carrier to record a graphical plot of the distance and direction traveled by the ship. The receivers, X1 and X2, are turned at the same rate as the speed rollers, L1 and L2, which are driven by the component disks, M1 and M2.

TRACKING MECHANISM

The tracking mechanism is located in the right-hand section of the DRT case (fig. 16-6).

It consists of a cross screw drive unit assembly and a lead screw drive unit assembly. The dial unit assembly of the DRI is also included in this mechanism. The north DRA transmitter actuates a receiver in the cross screw drive assembly, and the east DRA transmitter actuates a receiver in the lead screw drive assembly.

The cross screw drive unit assembly (fig. 16-5) consists of a receiver, X1, geared to the fluted shaft, Y, through a variable speed mechanism, Z1, and the standard-200 yd/in. shaft. The variable speed mechanism and gear shift assembly provide a means of changing the latitude scale to which the ship's course can be plotted from the standard-200 yd/in. scale to the 1/4 to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/in. scales.

The 200 yd/in. tracking scale is provided through a system of gearing that bypasses the variable speed friction drive assemblies that are employed when plotting to any of the other scales. To select the 200 yd/in. scale, the standard-200 yd/in. gear shift is set in the 200 yd/in. position. In this position of variable speed friction drive assemblies rotate but do not affect the 200 yd/in. tracking because no load is placed on the respective cluster gear bracket assemblies. To select any one of the three tracking scales, 1/4 to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/in., the standard-200 yd/in. gear shift is set in the standard position, and the 3-position miles-per-inch gear shift is set to the desired range scale. This connects the variable speed friction drive assembly to the fluted shaft, Y, through the selected gear ratio. A final adjustment allows any scale within the selected range to be used by a fine adjustment handle on the variable speed assembly. The handle moves the adjustable drive roller (connected to the rotor of receiver X1 through gears) along its axis of rotation to vary the distance of the driver roller from the center of the friction disk. A scale graduated in miles per inch is provided with a vernier dial graduated in hundredths of a mile per inch for fine adjustments.

The friction disk that is driven by the cross screw receiver, X1, drives the fluted shaft, Y, through gears. The rotation of this shaft is transmitted to the cross screw, K1, by two bevel gears H1 on the pencil carriage assembly, J2. This action moves the clasp nut attached to the pencil carrier, J1. The bevel gears and the cross screw are free to move along the fluted shaft while the shaft is rotating.

The lead screw drive unit assembly (fig. 6-5) consists of a receiver, X2, that is geared to the lead screw, K2, through a variable speed mechanism, Z2, and the standard-200 yd/in. gear shift. This variable speed mechanism and gear shift assembly are similar to those described in the cross screw drive unit assembly. They provide a means of changing the longitude scale to which the ship's course can be plotted from the 200 yd/in. scale to the 1/4 to 1 mi/in., 1 to 4 mi/in., or 4 to 16 mi/in. scales.

The friction disk that is driven by the lead screw receiver, X2, drives the lead screw, K2, through gears. The rotation of the lead screw, K2, moves the entire pencil carriage assembly, J2, along the tracking board. The cross screw, K1, is supported by an assembly that is geared to the lead screw, K2, by a clasp nut. As the receiver, X2, turns the lead screw, K2, the cross screw, K1, is moved to the right or left across the table, depending on the direction of rotation of X2. At the same time as the receiver, X1, turns the cross screw, K1, the pencil carrier, J1, is moved up or down, depending on the direction of rotation of X1.

Thus, as the lead screw and the cross screw are driven by their receivers in response to the impulses received from the DRA, the north and east components of the ship's motion are transmitted to the pencil. This action causes the pencil to move horizontally and vertically across the tracking board to trace a line that is the resultant of these components of the ship's travel. On a north or south course, only the cross screw is turned to trace a vertical line. On an east or west course, only the lead screw is turned to trace a horizontal line. On any other course, both the cross screw and the lead screw are turned to trace a line that bears the same relation to a vertical line as the ship's course bears to the meridian. The line represents, to scale, the actual course traveled by the ship.

A component tracking (interchange) switch, Z, is provided so that the north and east components inputs from the DRA can be interchanged to shift the plotting axes. This arrangement permits using the longer dimension of the tracking table as either north or east, depending on whether the ship's course is predominantly north-south or east-west. However, it is usually preferable to operate the DRT with the north component, actuating the cross screw, K1 (long dimension, east), as illustrated by the gear diagram in figure 16-5. Roller carriages E1 are provided to keep the pencil carriage assembly, J2, alined with the table.

The clasp nuts that drive the cross screw, K1, and the lead screw, K2, to transfer motion to the pencil carriage, J1, and the pencil carriage, J2, can be released. This arrangement permits moving the pencil independently of the screws to any desired position on the table. When they reach the end of the screws the clasp nuts disengage automatically, to prevent damage to the instrument.

CHART BOARD

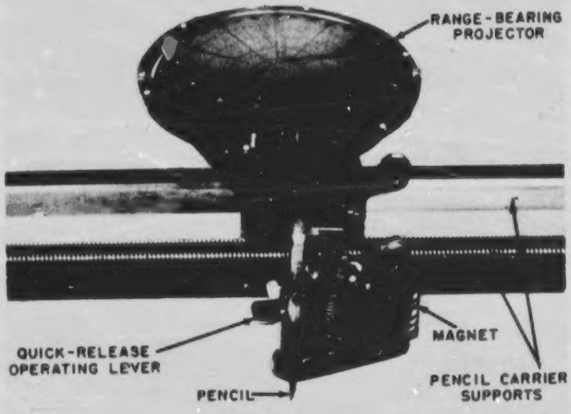
The chart board consists of a recessed plotting surface in the left-hand section of the DRT case below the pencil carrier assembly (fig. 16-6). The pencil automatically traces the movements of the ship on a chart inserted on the plotting surface.

The pencil carrier assembly, J1, is illustrated in figure 16-7. The pencil carrier assembly is supported by the pencil carriage assembly and includes the pencil, the pencil magnet, and the range-bearing projector. The pencil magnet is actuated by means of a clock-driven switch that energizes the pencil-magnet circuit at predetermined intervals. This action causes the magnet to lift the pencil from the chart periodically to omit the trace to facilitate interpreting the plot. The range-bearing projector (plotting light) is mounted on the pencil carrier for use in conjunction with the auxiliary plotting board to indicate the (own) ship's position at all times.

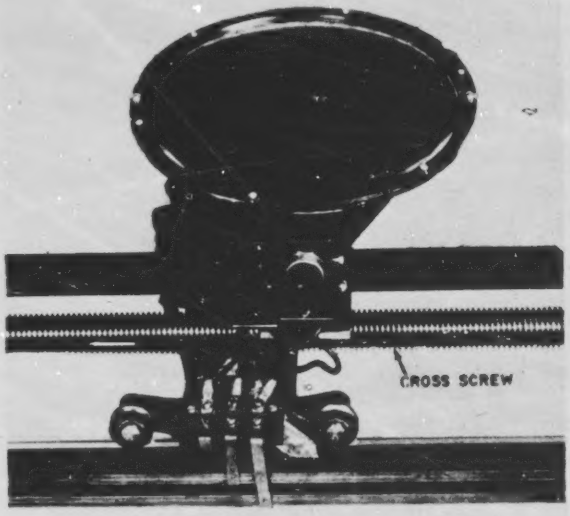
The pencil carrier is mounted on ball bearing rollers that travel in grooves provided in two supports located on either side of the cross screw (fig. 16-7A). These supports are part of the pencil carriage assembly and are therefore independent of the cross screw. Thus, the only contact the pencil carrier makes with the cross screw is through the threaded nut that converts the rotary motion of the cross screw into linear motion of the pencil and range-bearing projector.

The pencil can be set to any position within 0.1 in. of a designated point by two operating levers that actuate the quick-release nuts that run against the cross screw drive and the lead screw drive. These levers can be reached either through the side access doors in the DRT case, or by lifting the plotting board cover.

Two reset handwheels are provided for more precise setting of the pencil than to 0.1 in. (fig. 16-5). The reset handwheel mounted adjacent to the tracking-mechanism end of the case moves the pencil carrier along the cross-screw axis; whereas, the reset handwheel mounted at the chart-board end of the case moves the entire carriage assembly along the lead-screw axis.



A. FRONT VIEW



B. REAR VIEW

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Figure 16-7. — DRT pencil carrier assembly.

The pencil magnet and the range-bearing projector light are connected to three sliding contacts (on the pencil carrier) that bear on a three-bus trolley circuit mounted on one of the pencil-carrier supports (fig. 16-7B). The third bus is provided so that the pencil magnet and the range-bearing projector light can be used either separately or simultaneously. Three brushes, located at the end of the three-bus trolley circuit opposite the bevel gears, bear on three stationary contact rails that are supplied with the ship's 120-volt, d-c power.

General illumination for the DRT is provided by lamps located inside the chart-board and the tracking-mechanism areas. The lighting supply, which can be either a-c or d-c, is connected to a terminal block mounted on the partition between the chart board and tracking mechanism. A variable resistor in series with this circuit controls the intensity of illumination.

AUXILIARY PLOTTING BOARD

The auxiliary plotting board is a large glass surface mounted in a frame that is hinged to the DRT case (fig. 16-6). This plotting surface is furnished in conjunction with the DRT for plotting ranges and bearings of surface targets obtained from points along the (own) ship's course. It consists of a (1) flush top plotting surface to facilitate the use of a drafting machine (universal), and (2) range-bearing projector assembly mounted on the pencil carrier.

The range-bearing projector includes a light that projects an image on an appropriate chart placed on the plotting board (fig. 16-7). This image consists of five uniformly spaced concentric circles with a dot in the center of the innermost circle denoting the (own) ship's position. The plotting scale must be the same as the tracking scale for which the tracking mechanism is adjusted.

The range and bearing of a target with respect to the (own) ship is plotted from the center dot of the projected image. If the plotted radius is less than 5 in., the range and bearing will fall within the projected area. However, if the plotted radius exceeds 5 in., it is necessary to use a drafting machine.

The drafting machine is mounted on the frame of the glass plotting surface. It consists of a range ruler mounted from the center of a compass rose that is attached to a linked arm, and can be moved to any position on the plotting board. The range ruler can be set on any required bearing and when locked in place will remain on the same bearing irrespective of the movement of the compass rose.

OPERATION AND MAINTENANCE

The wiring diagram of the dead reckoning system is given in figures 16-8A and 16-8B. This system includes the (1) distance transmitter circuits, 2Y; (2) course followup circuits, LC; (3) step transmitter circuits, 1TL; and (4) pencil-magnet and projector-light circuits.

The DRE switch on the repeater panel is an ON-OFF switch. When this switch is closed, the rotor of the input course synchro receiver and the course followup motor are energized from the ship's single-phase, 120-volt, 60-hertz power supply; the 1-speed transmitter on the master compass provides an indication of the ship's course; the underwater log transmitter provides an indication of the ship's distance; and the step transmitters, step receivers, and pencil-magnet circuit are energized from the ship's d-c 120-volt power supply.

DISTANCE TRANSMITTER CIRCUITS

The input to the log distance transmitter circuits of the dead reckoning equipment is fed from the log distance transmitter to the DRE switch on the repeater panel (fig. 16-8B). When this switch is closed, the stator leads, S1, S2, and S3, of the long distance transmitter are connected respectively to the terminals, 2Y301, 2Y302, and 2Y303, on the repeater panel. These terminals are connected to the terminals, 2Y1, 2Y2, and 2Y3, respectively, in the DRA.

The distance input receiver, G, in the DRA is a differential-type synchro having wye-connected stator windings and wye-connected rotor windings. The rotor leads, R1, R2, and R3, of this differential synchro receiver are connected, respectively, to the stator leads, S1, S2, and S3, of the log distance transmitter. The stator leads, F1, F2, and F3, of the differential synchro receiver (F1 and F3 connected together) are connected respectively to the rotor leads, R1 and R2, of the log distance transmitter, which is energized through the terminals, 2Y and 2YY, in the DRA from the ship's single-phase, 120-volt, 60-hertz power. This arrangement provides the necessary field excitation to produce motor torque so that the receiver matches the rotation of the log distance transmitter. The differential synchro receiver is employed instead of a conventional synchro receiver to obtain more reliable operation. If the primary power supply to the synchro differential receiver should fail, the torque and output would drop to values insufficient to operate the receiver; whereas, in an ordinary synchro receiver, the salient pole rotor might develop sufficient torque to lock in at either 0° or 180°, and continue to operate with reduced torque, causing the equipment to be inaccurate.

COURSE FOLLOWUP CIRCUITS

The input to the course followup circuits of the dead reckoning equipment is fed from the 1-speed transmitter on the master compass to the DRE switch on the repeater panel (fig. 16-8B). When this switch is closed, the 1-speed transmitter stator leads, S1, S2, and S3, are connected to the terminals, LC131, LC132, and LC133, in the DRA. These terminals are connected respectively to the stator leads, S1, S2, and S3, of the course synchro receiver, V, in the DRA. The rotor leads, R1 and R2, of this course synchro receiver are connected, respectively, to the terminals, LC130 and LCC130 (in the DRA), which are energized from the ship's single-phase, 120-volt, 60-hertz power through the DRE switch on the repeater panel. An overload relay in the stator circuit between the DRE switch and the fuses on the repeater panel will indicate improper functioning of the course input synchro receiver, V, in the DRA by lighting a signal light on the repeater panel.

The course followup motor, U, in the DRA is an a-c commutator type series motor. It is energized from terminals LC130 and LCC130. Terminal LC130 is connected to the contact synchro receiver, V. This arm can contact either split ring segment F1 or F2 in the followup head, depending on the direction of rotation of the course followup motor, U. These ring segments are connected respectively, to the field terminals, F1 and F2, of the course followup motor. The motor field windings are arranged so that when the contact arm is on one split ring segment, current flows through one winding and the motor turns in one direction. Conversely, when the contact arm is on the other split ring segment, current flows through the other winding and the motor turns in the opposite direction. The armature of the followup motor is in series with the energized field. The other side of the armature is connected through terminal A1 to terminal LCC130 through R2. Resistor R2 limits the current through the motor. Resistor R1, in series with capacitors C1 and C2 that are connected, respectively, to leads F1 and F2, prevents sparking at the contacts in the split ring assembly.

STEP TRANSMITTER CIRCUITS

The north and east step transmitters, O1 and O2, in the DRA convey the north-south and east-west components of the ship's travel from the roller carriages, P1 and P2, to the pencil, J1, in the DRT and to the latitude and longitude dial receivers, V1 and V2, in the DRI.

A simple step transmitter-receiver circuit is illustrated in figure 16-9. The circuit is energized from the ship's 120-volt, d-c power. The step transmitter includes an eccentric arranged to operate three contacts in succession to close one side of the line, and a common contact that remains closed to complete the circuit. These three contacts energize coils in the step receiver in a definite sequence to cause the receiver rotor to rotate an amount proportional to the rotation of the transmitter. The rotor has four salient poles without windings.

The three transmitter contacts, 1, 2, and 3, are spaced 120° apart. Each is adjusted to make contact during 180° of the revolution of the eccentric to allow a 60° overlap in the closing of adjacent contacts. Each transmitter contact is connected to a pair of diametrically opposite coils in the six-pole step receiver.

When transmitter contact 1 closes to energize receiver coils 1 and 4, the closest pair of armature poles line up with these coils. Transmitter contact 2 closes 60° before contact 1 opens and energizes receiver coils 2 and 5 to make coils 1 and 2 opposite in polarity. This condition causes the receiver armature to rotate 15° in a clockwise direction, tending to line up the closest pair of adjacent poles with the axes of coils 1 and 2. Next, transmitter contact 1 opens and the receiver armature rotates another 15° clockwise to line up the closest pair of armature poles with the axes of coils 2 and 5. A similar sequence occurs when transmitter contact 3 closes and contact 2 opens 60° later. Thus, a 60° rotation of the transmitter causes the receiver to rotate 15°, resulting in a 4 to 1 ratio between the revolutions of the transmitter and receiver.

The step transmitter circuits of the dead reckoning equipment are supplied from the ship's 120-volt, d-c power to the DRE switch on the repeater panel (fig. 16-8B). When this switch is

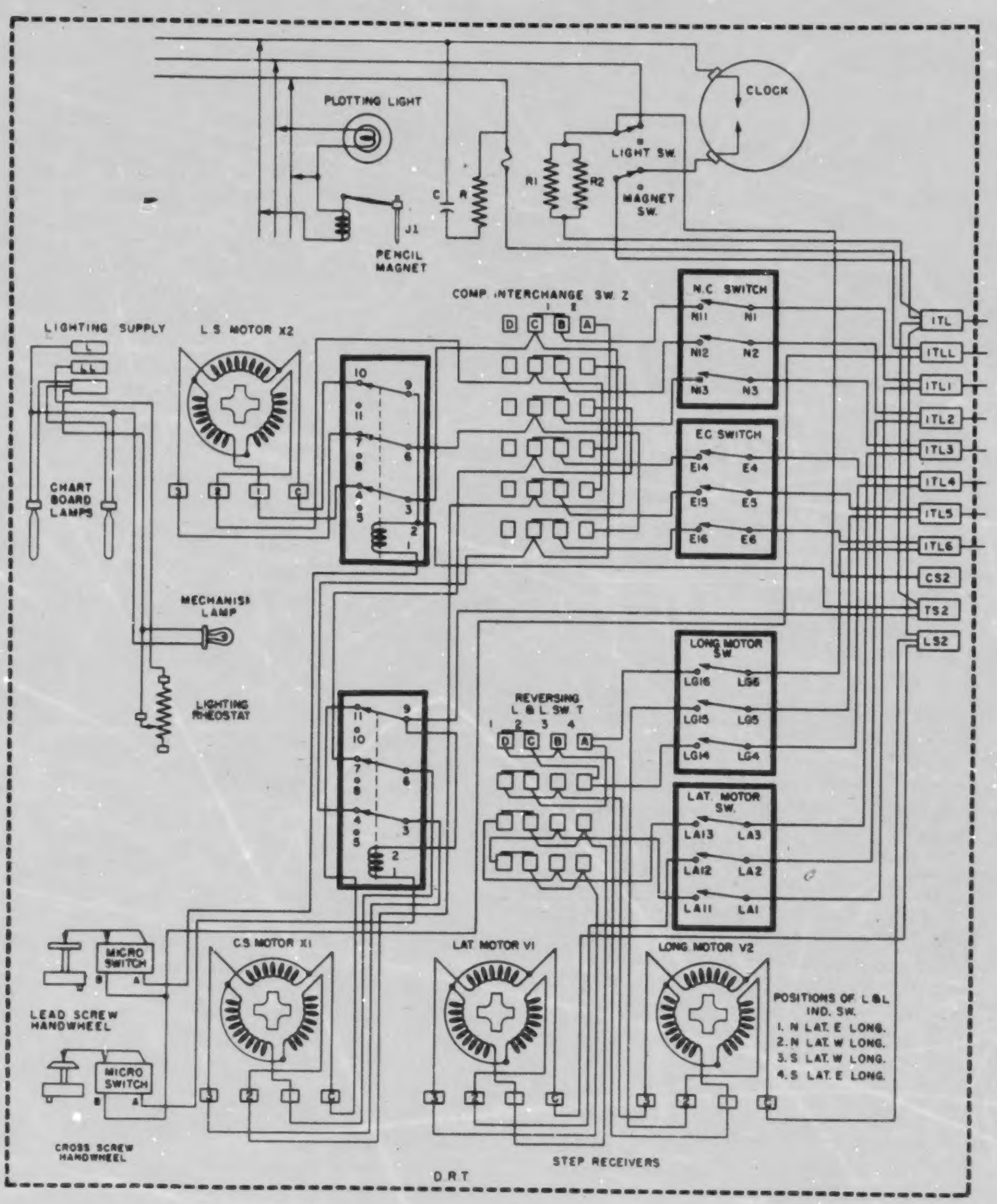
PLOTTING LIGHT
CLOCK
LIGHT SW.
MAGNET SW.
R1
R2
C
R
J1
PENCIL MAGNET
COMP. INTERCHANGE SW. Z
D
C
B
A
N.C. SWITCH
N11
N1
N12
N2
N13
N3
EC SWITCH
E14
E4
E15
E5
E16
E6
LIGHTING SUPPLY
L
LL
L.S. MOTOR X2
CHART BOARD LAMPS
MECHANISM LAMP
LIGHTING RHEOSTAT
ITL
ITLL
ITL1
ITL2
ITL3
ITL4
ITL5
ITL6
CS2
TS2
LS2
LONG MOTOR SW.
LG16
LG6
LG15
LG5
LG14
LG4
REVERSING L & L SW. T
LAT. MOTOR SW.
LA13
LA3
LA12
LA2
LA11
LA1
MICRO SWITCH
LEAD SCREW HANDWHEEL
MICRO SWITCH
CROSS SCREW HANDWHEEL
C.S. MOTOR X1
LAT MOTOR V1
LONG MOTOR V2
POSITIONS OF L & L IND. SW.
1. N LAT. E LONG.
2. N LAT. W LONG.
3. S LAT. W LONG.
4. S LAT. E LONG.
STEP RECEIVERS
D.R.T.

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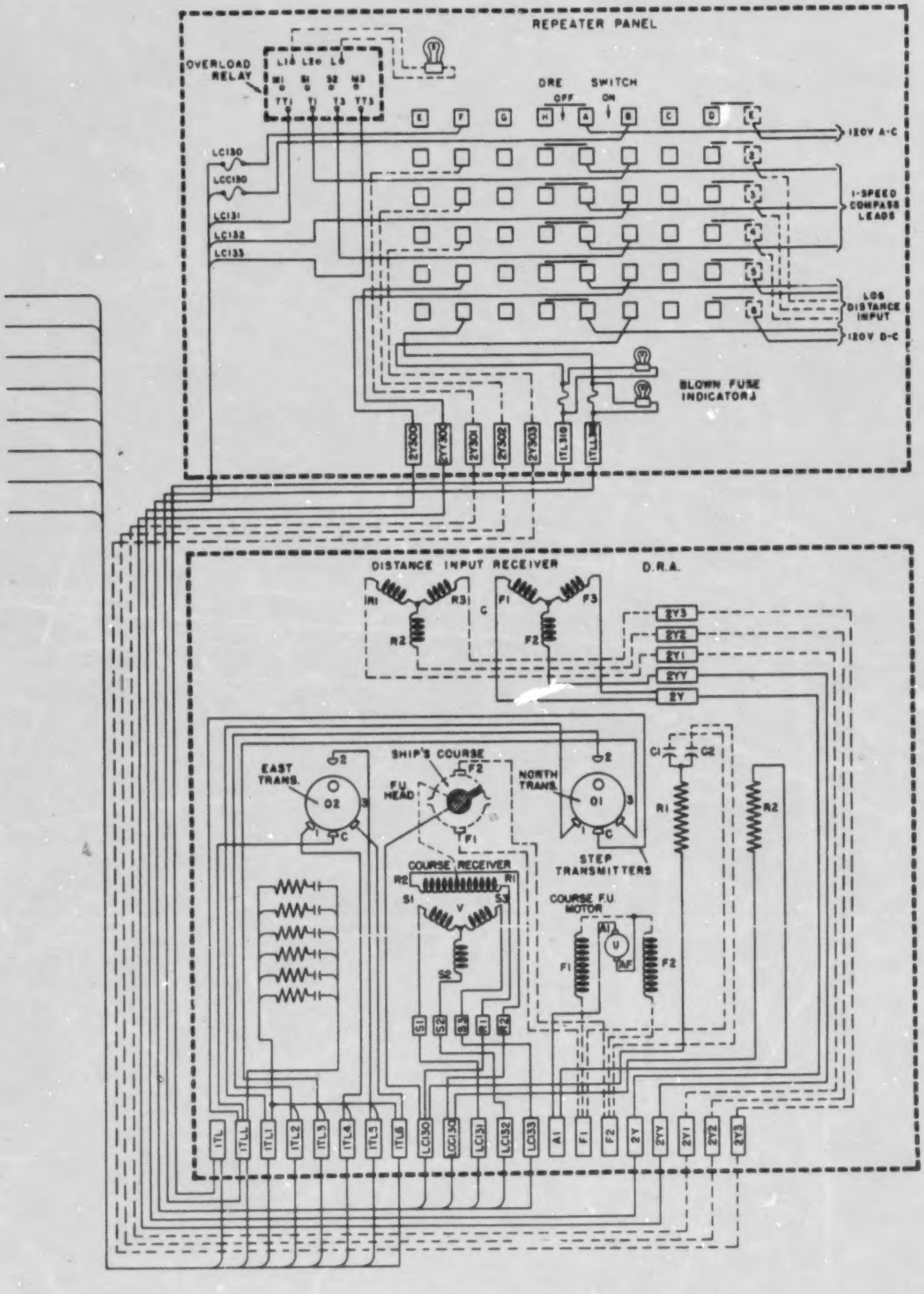
Figure 16-8A.—Dead reckoning system, wiring diagram.


REPEATER PANEL
OVERLOAD RELAY
L1 L2 L
M1 S1 S2 M3
TT1 T1 T3 TT3
DRE SWITCH
OFF
ON
E F G H A B C D E
2
3
4
5
6
LC130
LCC130
LC131
LC132
LC133
120V A-C
1-SPEED COMPASS LEADS
LOG DISTANCE INPUT
120V D-C
BLOWN FUSE INDICATORS
2Y300
2YY300
2Y301
2Y302
2Y303
1TL310
1TLL310
DISTANCE INPUT RECEIVER
D.R.A.
R1
R3
R2
C
F1
F3
F2
2Y3
2Y2
2Y1
2YY
2Y
EAST TRANS.
O2
SHIP'S COURSE
F.U HEAD
NORTH TRANS.
O1
STEP TRANSMITTERS
C1
C2
R1
R2
COURSE RECEIVER
S1
S2
S3
V
COURSE F.U MOTOR
A1
U
AF
F1
F2
1TL
1TLL
1TL1
1TL2
1TL3
1TL4
1TL5
1TL6
LC130
LCC130
LC131
LC132
LC133
A1
F1
F2
2Y
2YY
2Y1
2Y2
2Y3

40.64

Figure 16-8B.— Dead reckoning system, wiring diagram.

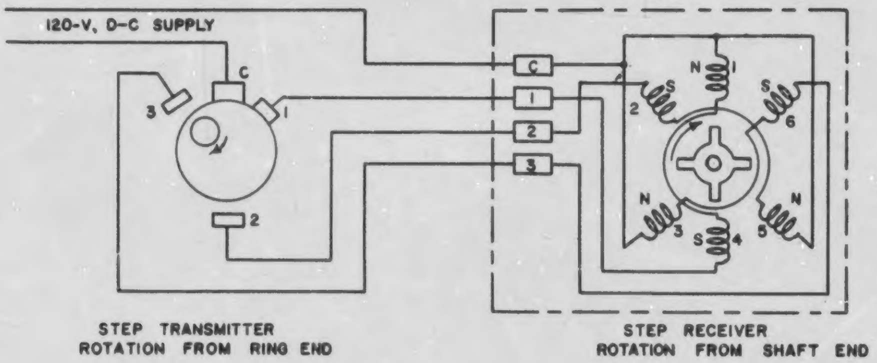


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Figure 16-9.—Step transmitter-receiver circuit.

closed, 120-volt, d-c power is supplied to terminals 1TL310 and 1TLL310 on the repeater panel. These terminals are connected to terminals 1TL and 1TLL respectively, in the DRA. Terminal 1TLL is connected to the common terminal, C, of both the north and east transmitters, 01 and 02. The return circuits from the transmitter contacts are to terminals 1TL1 to 1TL6, inclusive. These six transmitter terminals are connected to a resistance and capacitor bank that has a common return to terminal 1TLL. This resistance-capacitance bank is provided to prevent sparking of the transmitter contacts.

The DRA terminals, 1TL, 1TLL, and 1TL1 to 1TL6, inclusive, are connected to similar marked terminals in the DRT (fig. 16-8). The cross screw and lead screw receivers, X1 and X2, are connected to the terminals, 1TL1, to 1TL6, inclusive, through the component interchange switch, Z. Terminals 1TL1, 1TL2, and 1TL3 provide the north-south components of the ship's travel, and terminals 1TL4, 1TL5, and 1TL6 provide the east-west components of the ship's travel. The common terminals, C, of both receivers X1 and X2 are connected to terminal 1TL through terminal TS2 in the DRT.

A relay in series with each of the receivers, X1 and X2, is energized from terminals 1TL and 1TLL with the d-c supply through microswitches mounted adjacent to the cross screw and lead screw reset handwheels. These relays are provided to automatically open the circuits of the pencil-drive receivers when using the reset handwheels. When either handwheel is operated, the thrust required to mesh the reset gears will close the microswitch in the circuit of the associated relay coil. This action causes the relay armature to open the contacts in series with the associated pencil-drive receiver.

The latitude receiver, V1, connected to terminals 1TL1, 1TL2, and 1TL3, and the longitude receiver, V2, connected to terminals 1TL4, 1TL5, and 1TL6 are connected through the (dial) reversing switch, T. The common terminal, C, of both the latitude and longitude receivers is connected to terminal 1TL through terminal LS2.

It is usually preferable to operate the DRT component interchange switch, Z, in position 2. In this position the north component actuates the cross screw receiver, X1, and the east component actuates the lead screw receiver, X2. Thus, as the ship travels in a northerly direction, the pencil will move away from the fluted-shaft side of the case. Conversely, as the ship travels in an easterly direction, the entire pencil carriage assembly will move toward the tracking-mechanism end of the case.

In some installations it may be preferable to plot northerly travel of the ship along the lead screw axis. This is accomplished by setting the component interchange switch, Z, in position 1 to shift the plotting axes 90° counterclockwise. In this position the north component actuates the cross screw receiver, X1. In either position the common terminal, C, of the receivers is connected to the 1TL terminal of the DC supply through the respective relays.

Four 3-pole switches are provided in the receiver circuits (fig. 16-8A) so that the receivers, X1, X2, V1 or V2, can be turned on or off independently while the equipment is in operation.

PENCIL-MAGNET AND PROJECTOR-LIGHT CIRCUITS

The pencil-magnet and range-bearing projector-light circuits are energized from the ship's 120-volt, d-c power through terminals 1TL, 1TLL, and CS2 in the DRT (fig. 16-8A).

When the pencil-magnet switch is closed, the circuit from terminal 1TL includes the magnet switch, clock, pencil magnet, fuse, and terminal 1TLL. A capacitor, C, and resistor, R, that are connected across the magnet coil reduce sparking at the clock contacts.

When the light switch is closed, the circuit from terminal 1TL includes the parallel-connected resistors, R1 and R2, the light switch, the plotting light, the fuse, and terminal 1TLL.

When the dead reckoning system is placed in operation, all switches should be in the OFF position, and the minute dials of the latitude and longitude dials of the DRT should be set to indicate the latitude and longitude of the ship. The latitude and longitude receiver switches should be turned to the ON position.

An appropriate chart on which the ship's course is to be plotted is tacked on the chart board and the desired reference lines are drawn. The course to be plotted should be considered, and the pencil should be placed so that it will not run off the chart on one side and leave a large unused section on the other side of the chart. The pencil is located by disengaging the clasp nuts on the pencil carriage and moving the pencil to the desired location. The north and east component receiver switches are now turned to the ON position.

The miles-per-inch setting of the DRT, for both the north and east components, should be adjusted to a value consistent with the length of the course to be plotted and the space available on the chart. Both settings should be adjusted to the same miles-per-inch scale to avoid the necessity of computing the number of miles for a given course.

The latitude and longitude (dial) reversing switch, T, of the DRT is set to the proper earth's quadrant in which the ship is operating. The latitude and longitude receivers will rotate in the proper direction, causing the latitude and longitude dials to indicate correctly. The proper position of this switch must be selected when crossing the equator the 0° meridian, or the 180° meridian.

The component interchange switch, Z, of the DRT is set to the desired plotting axes as indicated on the nameplate under the switch handle. As previously stated, this switch provides for shifting the plotting axes at right angles to each other to orient the north in either of the two available directions on the chart board.

The clock switch on the DRT can be turned to the OFF or ON position, depending on whether or not it is desired to plot the course with a time element.

When the DRE switch is turned to the ON position the course receiver takes its proper position, and the followup motor brings the crank arms to their proper position. The step receivers in the DRT and the distance input receiver in the DRA revolve in synchronism with their respective transmitters.

ELECTRICAL TROUBLES

In the event of electrical troubles the most important thing to remember is that the DRE was properly wired and tested before installation and checked again afterward. Therefore, permit no alterations in wiring. The most common cause of electrical failures are loose connections, blown fuses, and dirty or worn motor or step transmitter brushes. Unless you have reason to believe that the trouble is in a specific section of the DRE, begin at the source of the power supply and test the circuit progressively with a multimeter until the trouble is located.

Distance Input Receiver

If the distance input receiver does not operate, test for 115-volts a-c at terminals 2Y and 2YY (fig. 16-8B). Failure of the field supply to the distance input motor will also result in failure of the course motor, as both fields are supplied from the same source.

The following test can be made on the distance input receiver when the ship is not under way. Close the DRE switch and read these voltages at terminals 2Y301-2Y302, 2Y302-2Y203, 2Y303-2Y301 (fig. 16-8B). These voltages may vary from zero to about 100 volts.

Compass Controlled Followup

When the followup motor does not work, test for 115-volts a-c at terminals LC 130 and LCC130 (fig. 16-8B) and check the motor circuit for continuity. Short-circuited capacitors (either C1 or C2), or an open circuit in resistor R1, will cause excessive sparking at the contacts (of the followup head), but will not make the motor inoperative.

If the followup motor moves the contact to either dead space between the semicircular rings (of the F.V. head) but the compass reading is incorrect, remove the field connections from terminals LC130 and LCC130 and test the field circuit for continuity. The course-indication voltages from the gyrocompass transmitter can be checked by measuring three voltage values at terminals LC131-LC132, LC132-LC133, and LC133-131. These will vary from zero to 90 volts. Inspect the fuses on the repeater panel and make continuity tests within the circuits which include the brushes of the course receiver; do so after removing connections from terminals LC131, LC132, and LC133.

If the receiver rotor is restrained by a mechanical fault from moving to its proper position within the stator, excessive current will flow in the rotor and stator windings. This fault is indicated by the overload lamp glowing on the repeater panel.

Step Transmitters and Receivers

Erratic action of the step receivers may be caused by open circuits, worn transmitter brushes, or shorted capacitors. Test those parts as directed in the specific manufacturer's technical manual where information is given for rapidly evaluating the condition of suspected items. As with all IC service work, the knowledge of basic principles must be supplemented by practical experience. The leading IC Electrician should be confident about his evaluation of suspected parts being good or bad. When in doubt, a suspected part should be replaced with a new one.

Pencil Magnet

Trouble in the pencil magnet circuit may be caused by open circuits, or a short-circuited pencil magnet coil. Look for a blown fuse in the tracking unit. Check the supply voltage and inspect the sliding contacts. If the pencil magnet coil works only when the clock terminals (fig. 16-8A) are shorted during tests, the clock contacts are at fault. While the clock (in good or bad condition) is intentionally shorted, the use of a 115-volt d-c voltmeter can disclose a hidden broken connection that is located elsewhere within the circuit because the meter will deflect, but only when its test leads are placed on terminals that include the broken connection.

A short-circuited pencil magnet is indicated when the circuit is found to be continuous and the pencil magnet does not operate.

A defective 0.5-mfd capacitor or 150-ohm resistor (C or R, fig. 16-8A) will burn and wear out the contacts of the clock by excessive sparking but will not make the pencil magnet inoperative.

DRE IMPROVEMENTS

The Navy's newest Dead Reckoning Equipment comprises a Mk 9 Mod 4 Dead Reckoning Analyzer Indicator (DRAI) and the Mk 6 Mod 4B Dead Reckoning Tracer (DRT). Figure 16-10 is a block diagram of this equipment.

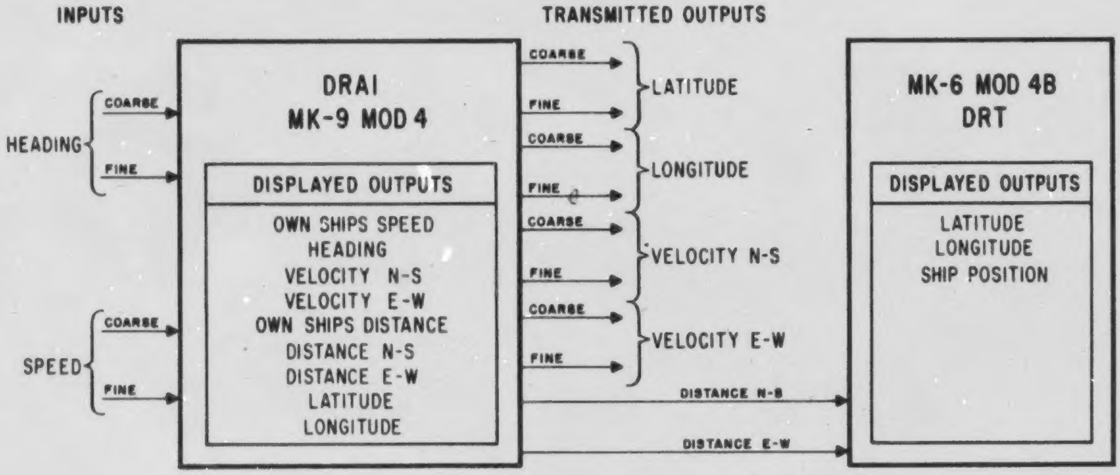
DEAD RECKONING ANALYZER INDICATOR MK 9 MOD 4

The Mk 9 Mod 4 DRAI (fig. 16-11) is a hybrid analog/digital computer which continuously computes, transmits and displays principal navigation information. This DRAI accepts synchro information of own ship's speed (OSS) from the ship's underwater log system and own ship's heading (OSH) from the ship's gyrocompass system. Dead reckoning parameters are calculated from these signals and displayed on the front of the DRAI by various dials and counters. Some of these parameters are electrically transmitted to related shipboard equipments.

The DRAI is used aboard surface ships and submarines. It can drive up to four DRTs simultaneously. The DRAI is constructed in three subsystem groups: analog servo modules, digital printed circuit cards, and power supply and excitation components.

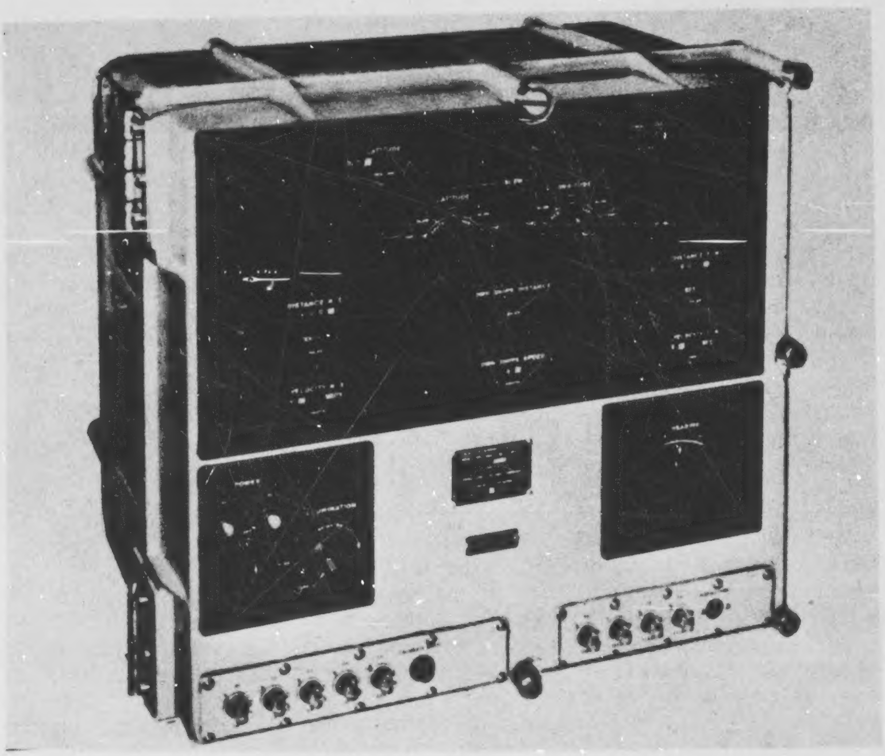
Analog Servo Modules

The analog servo modules A2A1 through A2A8 are mounted at the rear of the frame door. See figures 16-12 and 16-13. Each is a separate, removable, servo package entirely self-contained except for system electrical interconnections. Each servo module has its own dial or counter indicator, which is visible through edge-lighted, front panel cutouts. The servo modules can be completely removed from the equipment and bench tested through the use of a module extender test cable that is supplied with the equipment.


INPUTS
TRANSMITTED OUTPUTS
HEADING
COARSE
FINE
SPEED
COARSE
FINE
DRAI
MK-9 MOD 4
DISPLAYED OUTPUTS
OWN SHIPS SPEED
HEADING
VELOCITY N-S
VELOCITY E-W
OWN SHIPS DISTANCE
DISTANCE N-S
DISTANCE E-W
LATITUDE
LONGITUDE
COARSE
FINE
LATITUDE
COARSE
FINE
LONGITUDE
COARSE
FINE
VELOCITY N-S
COARSE
FINE
VELOCITY E-W
DISTANCE N-S
DISTANCE E-W
MK-6 MOD 4B
DRT
DISPLAYED OUTPUTS
LATITUDE
LONGITUDE
SHIP POSITION

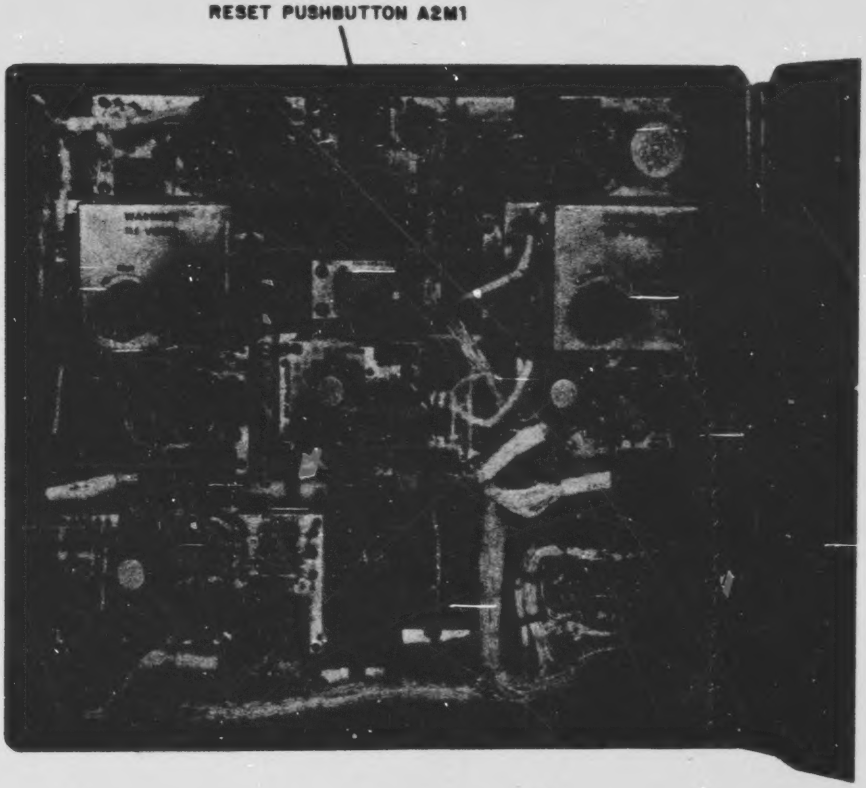
40.56(40D)

Figure 16-10. — Block diagram of the Mk 9 Mod 4 DRAI and Mk 6 Mod 4B DRT.



40.147(40D)

Figure 16-11. — DRAI Mk 9 Mod 4 dead reckoning analyzer indicator.



40.169

Figure 16-12.—Module frame assembly.

Digital Printed Circuit Cards

Digital printed circuit cards A1A1A1A3 through A1A1A1A8 are plug-in units mounted in a conventional card file (fig. 16-13). The printed circuit cards are accessible for troubleshooting by means of the card extender test board that is supplied with the equipment.

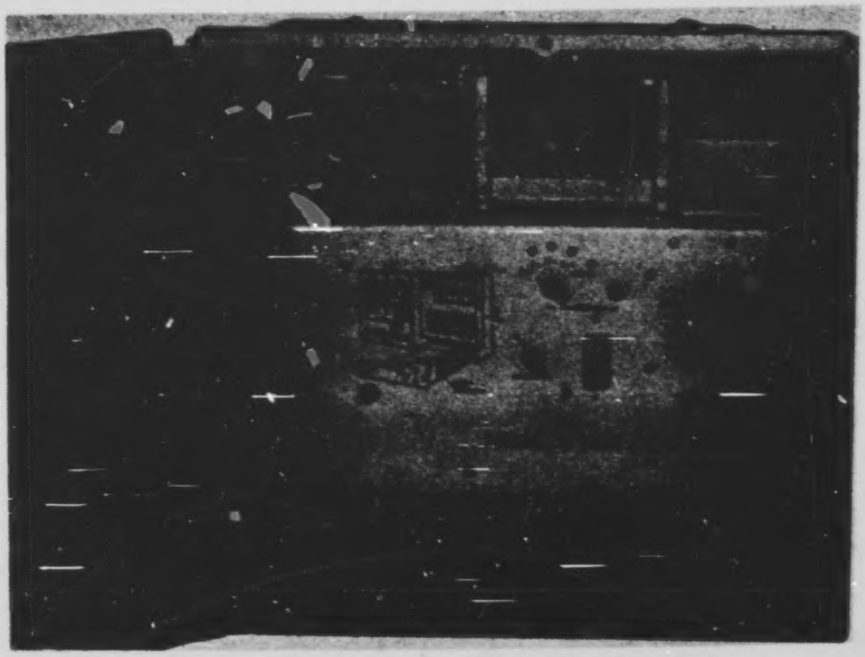
Power Supplies

Power supplies PS1 and PS2, both plug-in modules, are made accessible by dropping down the A1A2 (hinged panel) assembly. The Mk 9 Mod 4 DRAI requires two voltage supplies: 115-VAC, 400-hertz, single-phase at 3 amperes and 115-VDC at 6 amperes. It is compatible to any DRT that uses a d-c stepmotor. The north-south and east-west distance signal supplied by the Mk 9 Mod 4 DRAI is a d-c step signal at 750 Rev/mi, 6 pulses/rev.

DEAD RECKONING TRACER
MK 6 MOD 4B

The Mk 6 Mod 4B Dead Reckoning Tracer (DRT) (fig. 16-14) is used in a shipboard dead reckoning system. The DRT graphically records own ship's dead reckoning track and computes and displays own ship's latitude and longitude on counters.

The DRT operates automatically from input signals of distance north and distance east from step transmitters, or equivalent, in the DRA or DRAI. The east and north components, after appropriate voltage reduction to 5 VDC, drives the lead and cross screws to move the pencil carriage/projector assembly and record the



40.170

Figure 16-13. — Hinged panel assembly.

ship's track. A switch is provided for rotating the tracking axes by 90 degrees. Latitude and longitude are continuously computed from the two distance inputs and are displayed on counters. No switching or adjustment is required when the Equator or Prime Meridian is crossed.

The Mk 6 mod 4B DRT is comprised of two major assemblies: the track compartment and the control compartment. See figures 16-15 and 16-16.

Trace Compartment

The trace compartment (fig. 16-16) contains the following:

1. Lead screw drive assembly
2. Cross screw drive assembly
3. Pencil assembly
4. Projector assembly
5. Tracking board
6. Auxiliary plotting surface

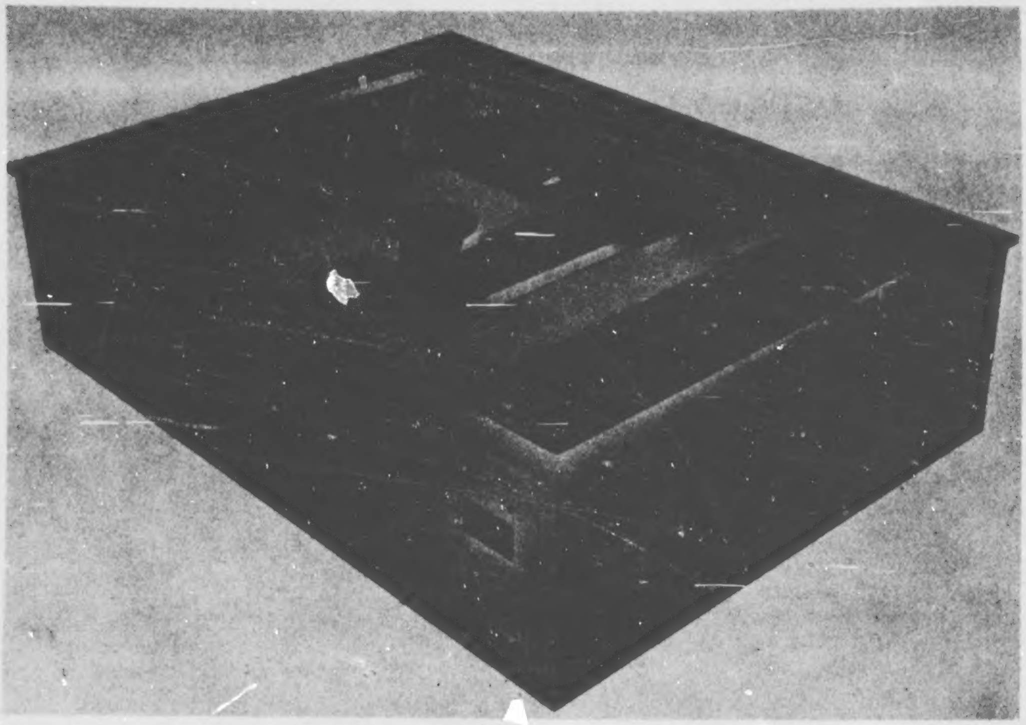
Control Compartment

The control compartment (fig. 16-15) contains the electronic portions of the DRT, all operation controls, and an eight-day mechanical clock. The major parts of the control compartment are:

1. Clock assembly
2. Control panel assembly
3. Card rack assembly
4. Transformer assembly
5. Clipper circuit assembly
6. Input terminal board assembly

The DRT is installed in the ship's CIC, Navigational Plot, and/or control space. It is designed for either horizontal or bulkhead mounting.

The design of the Mk 6 Mod 4B DRT has resulted in many improvements over the older mechanical DRTs. These improvements include: (1) low voltage application (that is, less torque applied to lead and cross screws); (2) equipment



40.61(40D)A

Figure 16-14.—Dead reckoning tracer Mark 6 Mod 4B.

that never requires lubrication; (3) only two gear trains of two gears each for the lead and cross screw drives; (4) capability of shifting to emergency tracking scale (200 yd/in.) by means of a toggle switch; (5) shifting of tracking scales by positioning a counter dial, thus eliminating hand cranking of mechanical gear trains; (6) computing its own latitude and longitude whether the tracer is used or not; and (7) generating its own calibration/alignment signals so that proper operation of the DRT can be determined without an external signal.

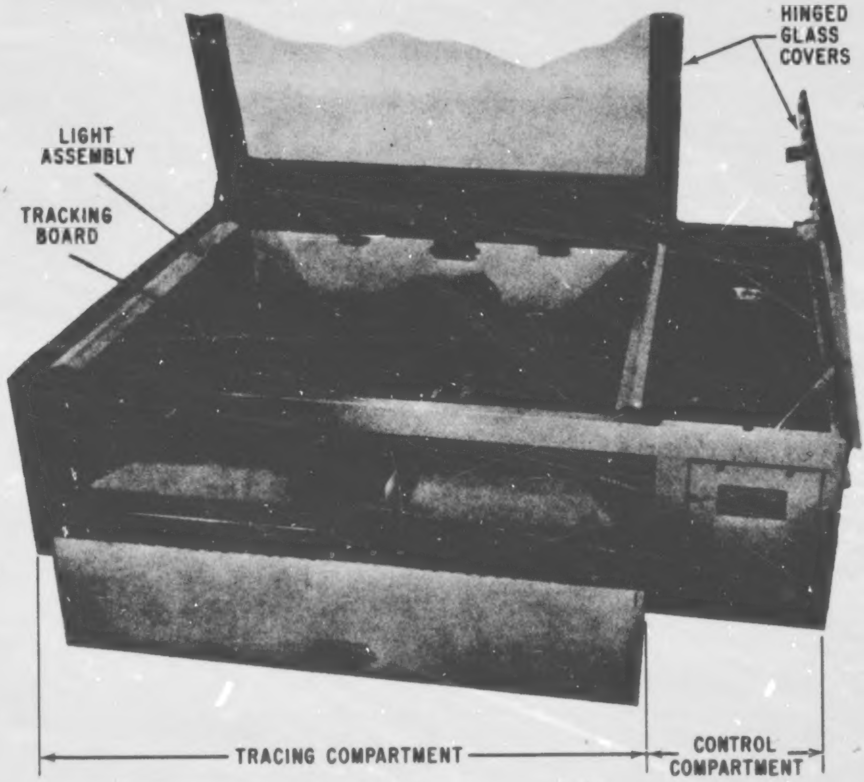
INTRODUCTION TO THE NC-2 PLOTTING SYSTEM

The Navigational Computer (NC-2) Plotting System has been modified and improved to the extent that has made it a highly sophisticated unit of the Navy's ASW, navigation, radar, and air operations.

The increased emphasis on ASW operations has led to the development of more complicated systems. The original NC-2 Mod 0 system was designed to plot own ship's position and two targets. The systems that have evolved from the NC-2 Mod 0 have the capabilities of plotting own ship's position and four targets. All the plotting systems provide own ship's latitude and longitude readouts to indicate the ship's geographical location.

The NC-2 systems currently in use are: Mod 0 (MARSLAND), Mod 1/1A (SPERRY), Mod 2/2A (HUYCK), and Mod 3 (HARTMAN), the newest system, which is also designated as the Tactical Display Plotter, PT 512/S.

The ASW Plotting Systems (fig. 16-17) Mk NC-2 Mods 2 and 2A are used in CIC or similar shipboard areas for dead reckoning plotting of own ship's position and moving or stationary underwater, surface, or airborne targets. The equipment is used during antisubmarine warfare or related tactical situations, and as an aid to navigation.



40.61(40D)B

Figure 16-15. — Dead reckoning tracer compartments.

The systems consist of two units each: (1) a Dead Reckoning Analyzer Indicator (DRAI) or a Dead Reckoning Indicator (DRI), which computes own ship's dead reckoning position and (2) a Plotting Table, which displays Own Ship's Position and the positions of four separate targets.

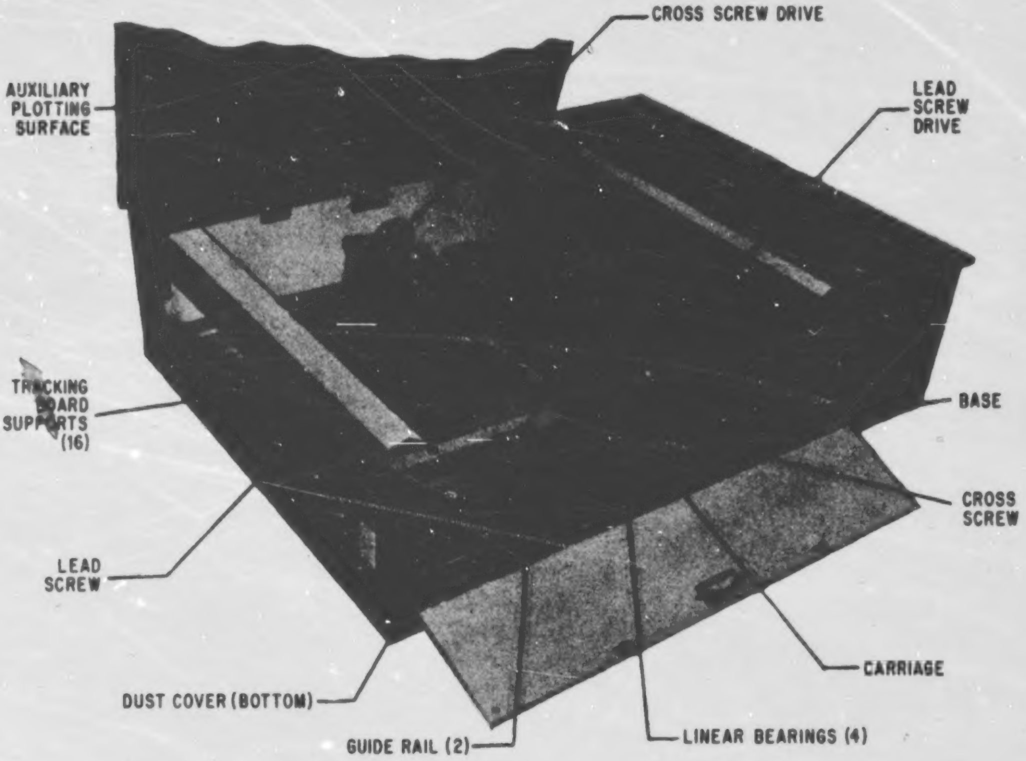
The Mk NC-2 Mods 2 and 2A are provided with identical Plotting Tables. The systems differ in that the Mod 2 is supplied with a DRI and the Mod 2A is supplied with a Mk 9 DRAI. Since the Mod 2A is the most common system used, its operation will be discussed.

MK 9 DEAD RECKONING ANALYZER INDICATOR

The Mk 9 DRAI (fig. 16-18) is designed for direct bulkhead mounting and can be operated as an independent unit or in conjunction with and as a part of the NC-2 Mod 2A Plotting System. When used with the NC-2 Plotting System, the DRAI is electrically connected to the NC-2 Mod 2 Plotting Table.

There are two versions of the DRAI used with the Mk NC-2 Mod 2 Plotter: the Mk 9 Mod 0 DRAI, designated the standard unit and the Mk 9 Mod 2 DRAI, designated as the low noise or "silent" unit. Only minor differences exist between the two versions. Except when noted, all information will apply to both versions.

The DRAI is an electromechanical computer that receives, as synchro signals, inputs of own ship's speed (OSS), and own ship's course (OSC). From these inputs, the north-south (N-S) and east-west (E-W) components of ship's speed are computed for internal use within the DRAI


CROSS SCREW DRIVE
AUXILIARY PLOTTING SURFACE
LEAD SCREW DRIVE
TRACKING BOARD SUPPORTS (16)
BASE
CROSS SCREW
LEAD SCREW
CARRIAGE
DUST COVER (BOTTOM)
LINEAR BEARINGS (4)
GUIDE RAIL (2)

40.61(40D)C

Figure 16-16.—Dead reckoning tracer with tracking board removed.

and for transmission to external shipboard equipment. In addition, OSS is integrated with respect to time to give a counter readout of total distance traveled.

The N-S and E-W speed components are also integrated to provide a counter readout of distance traveled in the N-S or E-W direction. The DRAI supplies a counter readout of ship's latitude and longitude, computed from the N-S and E-W components of ship's speed. The DRAI can transmit computed values of latitude, longitude, present ship's position in N-S and E-W components, own ship's speed N-S and E-W, and change of position in N-S and E-W components. Change of position values are computed with respect to manually established starting references, one for each coordinate N-S and E-W.

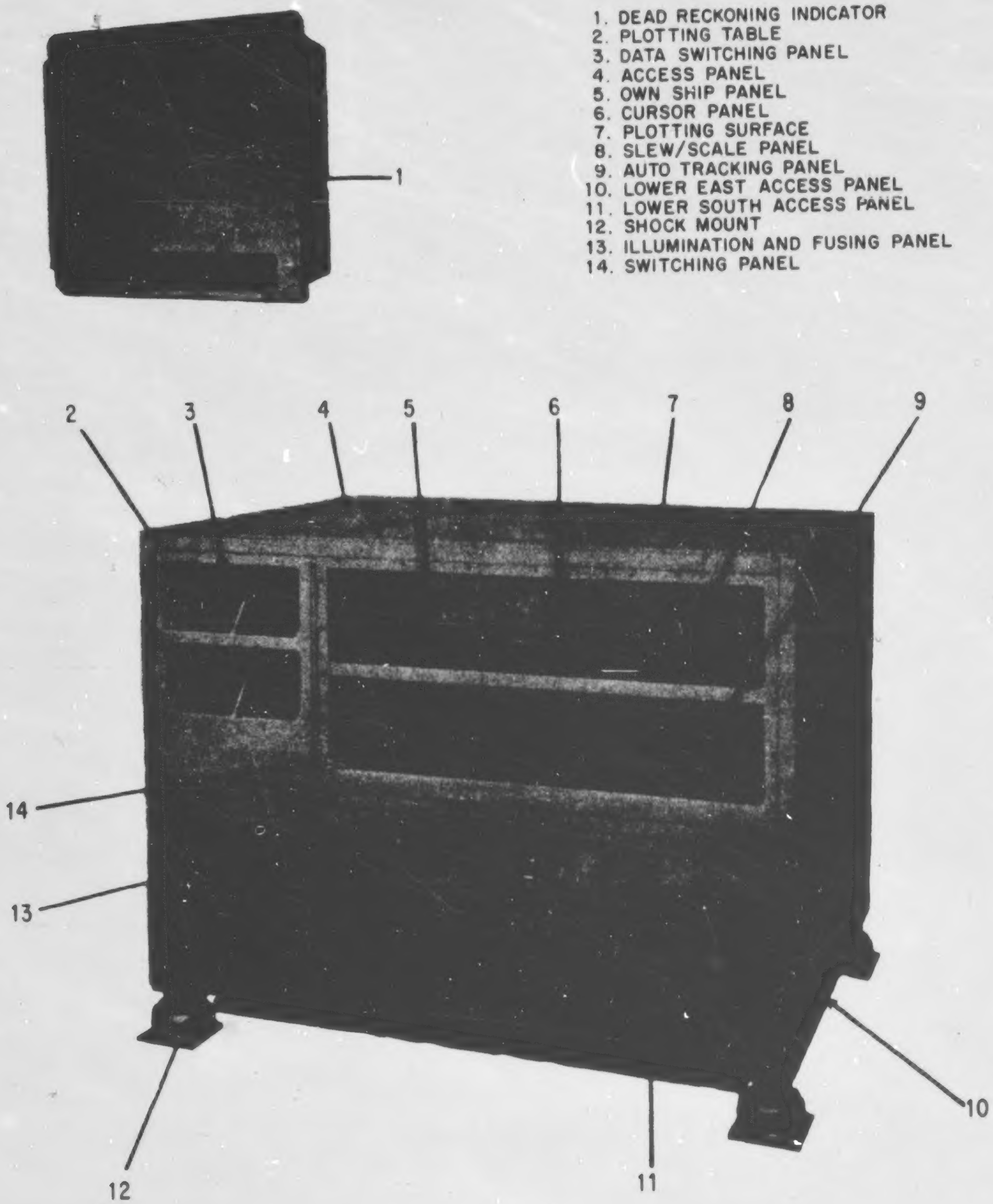
The DRAI has the capability of accepting two independent relative bearing input signals from the NC-2 Mod 2 Plotting Table and of converting these inputs to true bearing signals.

DRAI Functional Description

The DRAI consists of nine modules, designated 2A1 through 3A9, and five subassemblies, designated 3A10 through 3A14. The operation of each module and/or subassembly is discussed separately.

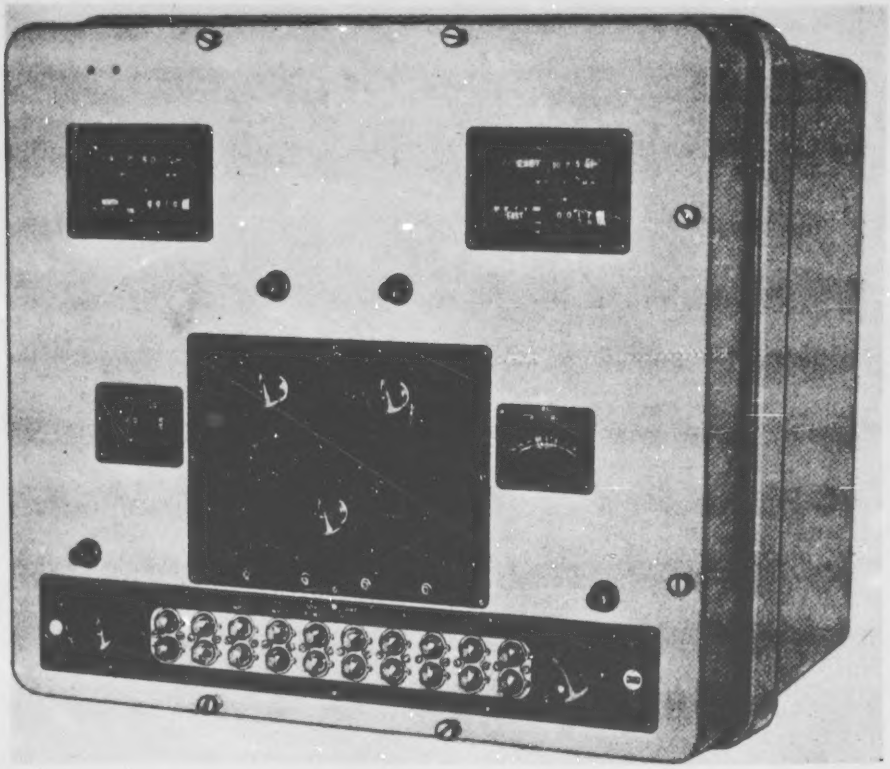
Own Ship's Speed Module (3A1)

The Own Ship's Speed Module (3A1) (fig. 16-19) contains two synchro control transformers (B1 and B3), servoamplifier A1AR1, servomotor B2, potentiometer R1, and relay A1K1. A cutover network is interposed between the two control transforms (CT) and the amplifier. The OSS module functions as a conventional servo


1. DEAD RECKONING INDICATOR
2. PLOTTING TABLE
3. DATA SWITCHING PANEL
4. ACCESS PANEL
5. OWN SHIP PANEL
6. CURSOR PANEL
7. PLOTTING SURFACE
8. SLEW/SCALE PANEL
9. AUTO TRACKING PANEL
10. LOWER EAST ACCESS PANEL
11. LOWER SOUTH ACCESS PANEL
12. SHOCK MOUNT
13. ILLUMINATION AND FUSING PANEL
14. SWITCHING PANEL
1
2
3
4
5
6
7
8
9
14
13
10
12
11

74.28(40D)A

Figure 16-17. — ASW plotting system Mark NC-2 Mod 2.



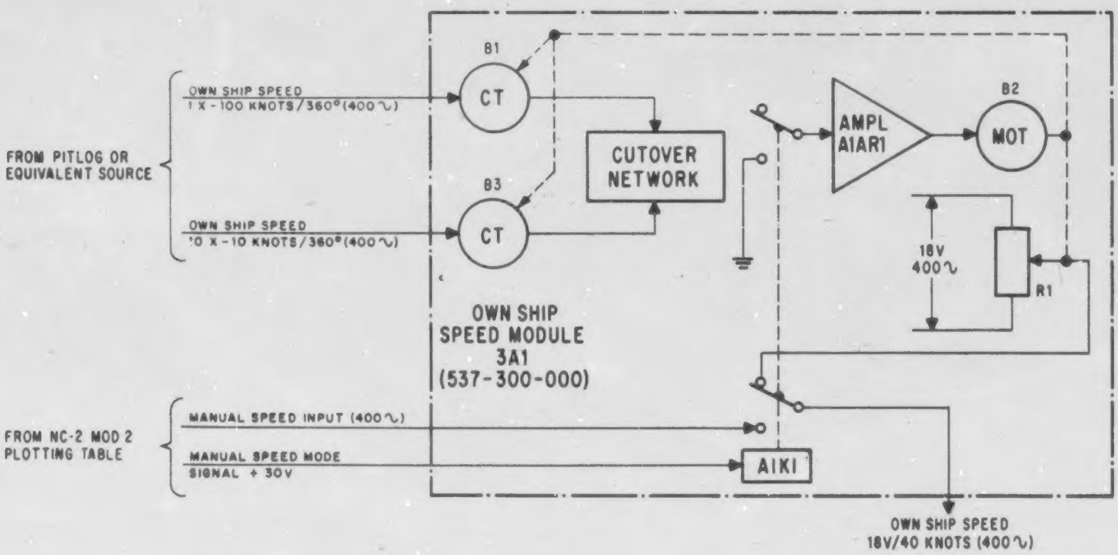
40.147

Figure 16-18.—Dead reckoning analyzer-indicator Mark 9 Mod 0.

loop. B1 and B3 receive the speed data from the underwater log. Their output is amplified by servoamplifier A1AR1 which drives servomotor B2. In driving to null, servomotor B2 positions the slider of the 10-turn potentiometer R1. The slider of R1 picks off a voltage representing ship's speed. For 40 knots of ship's speed the slider of R1 will pick off 18 VAC. Relay A1K1 is energized when a manual speed input is selected from the Plotting Table.

Own Ship's Course Module (3A2)

The Own Ship's Course Module (3A2) (fig. 16-20) is a conventional control transformer followup servo loop. The module has a two-speed dial to allow direct readout of own ship's course. Control transformers, B1 and B2, receive the two-speed synchro data from the gyrocompass. The cutover network determines whether B1 or B2 will supply an input to the servoamplifier AR1. Servoamplifier AR1 will drive servomotor B6. In driving the input signal to null, servomotor B6 positions the rotor of resolver B3, own ship's course dial, and the rotors of the two control differential transmitters B4 and B5. The speed voltage from module 3A1 is fed through the resolver amplifier AR2 (gain factor 0.96) to the stator of resolver B3. The electrical output of resolver B3 is the own ship's speed components in the N-S or E-W direction. B4 and B5 convert relative bearing inputs from the Plotting Table to true bearing. This true bearing data is sent to the Plotting Table. Turning networks, C2 and C3, allow the relative bearing data to be 60 hz or 400 hz. B4 and B5 are synchro differential transformers used for obtaining true


B1
OWN SHIP SPEED
1 X - 100 KNOTS/360° (400 ∿)
FROM PITLOG OR
EQUIVALENT SOURCE
CT
B3
OWN SHIP SPEED
10 X - 10 KNOTS/360° (400 ∿)
CT
CUTOVER
NETWORK
AMPL
A1AR1
B2
MOT
18V
400∿
R1
OWN SHIP
SPEED MODULE
3A1
(537-300-000)
FROM NC-2 MOD 2
PLOTTING TABLE
MANUAL SPEED INPUT (400 ∿)
MANUAL SPEED MODE
SIGNAL + 30V
A1K1
OWN SHIP SPEED
18V/40 KNOTS (400 ∿)

40.171

Figure 16-19. — Own ship's speed module (3A1).

bearing from electrical inputs of relative bearing and mechanical inputs of own ship's course. Whereas the other synchros used in the D.R.A.I. are all 400 hz, B4 and B5 may be operated at either 400 hz or 60 hz. When either is operated at 400 hz, the corresponding relay, K2 or K3, remains de-energized. The relays are operated from +30 V dc from an external source. When either relay is energized, the corresponding network, C2 or C3 is placed across the stator inputs of the differential transformer. Each capacitor unit is, in effect, a tuning network so that the effective impedance of the CDX remains the same, whether operated at 400 hz or 60 hz. B4 and B5 operate independent of each other. Relay K1 is made to operate when manual course data is supplied from the plotting table.

Own Ship's Speed N-S Module (3A3)

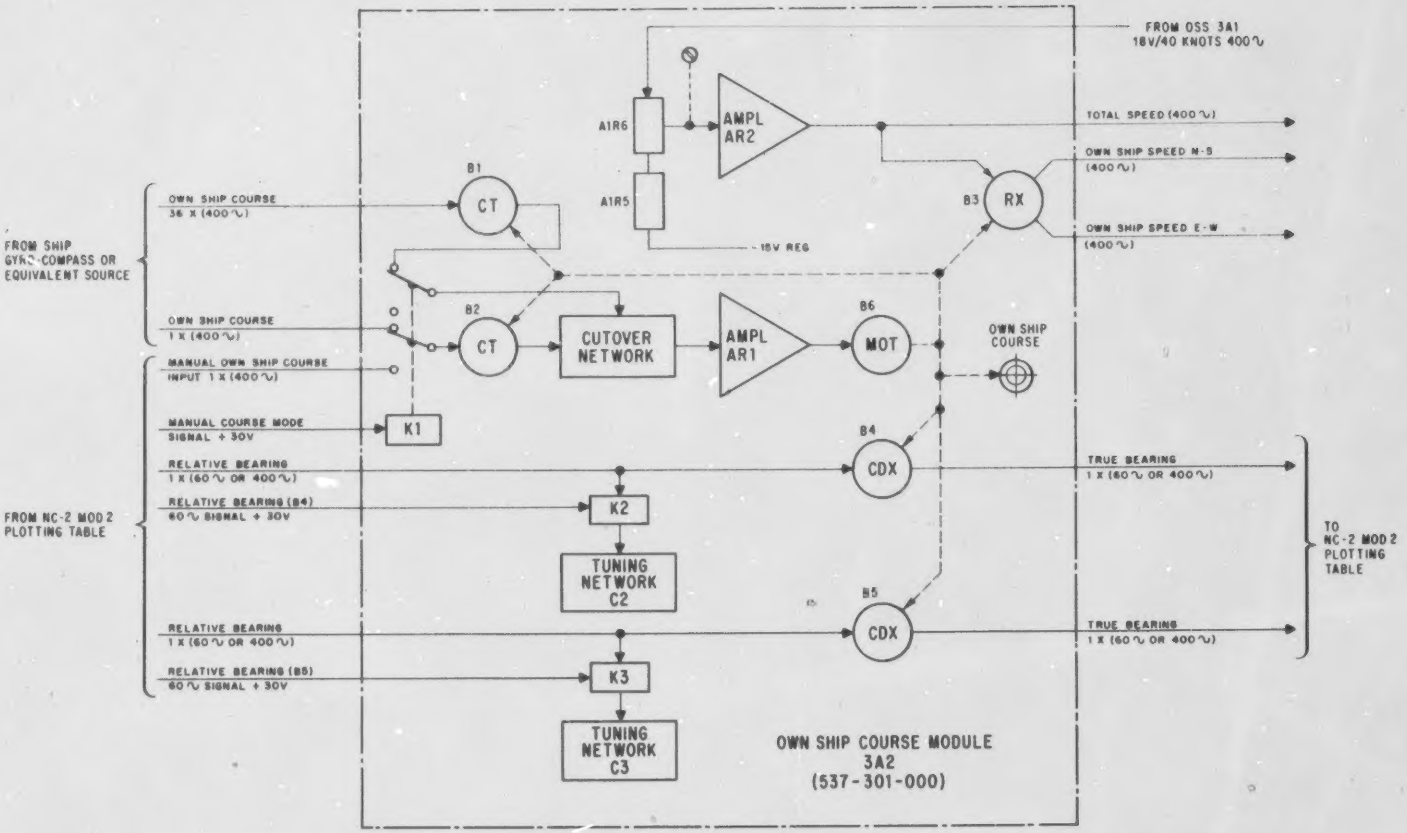
The Own Ship's Speed N-S Module (3A3) (fig. 16-21) receives, as an input, the N-S speed component signal from resolver B3 in the 3A2 module. This signal is applied to servoamplifier A1AR1, which drives servomotor B2. In driving, servomotor B2 positions the rotors of control transmitters B1 and B3 and the slider of potentiometer R1. Both B1 and B3 supply external equipment with a two-speed synchro signal representing own ship's speed N-S. The slider of potentiometer R1 picks off a voltage that is fed back to a summing junction in servoamplifier A1AR1 to null its input signal. The feedback voltage is 180 degrees out of phase with the input signal. When the feedback voltage amplitude is equal to the input signal, the servomotor stops driving.

Own Ship's Speed E-W Module (3A4)

The Own Ship's Speed E-W Module (3A4) is identical to the module 3A3. Both are physically and electrically identical and interchangeable.

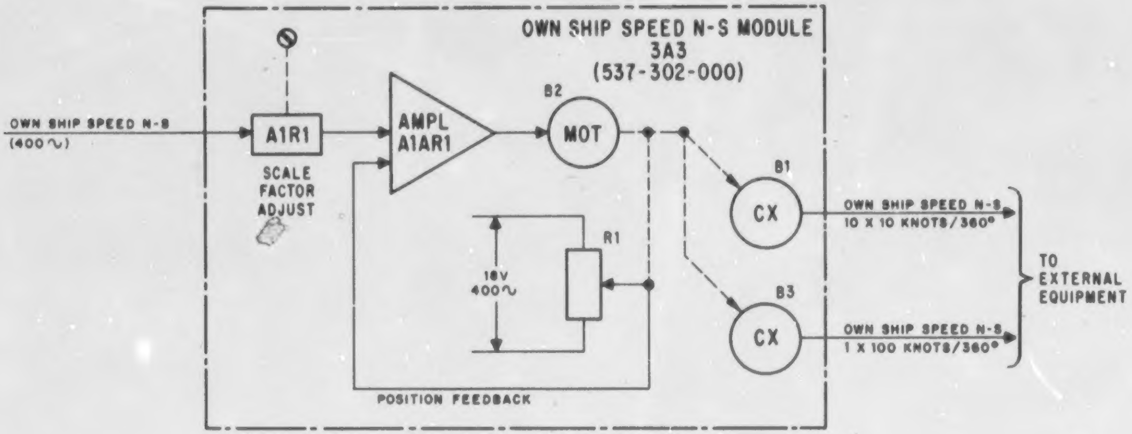
Own Ship's Distance Module (3A5)

The Own Ship's Distance Module (3A5) (fig. 16-22) consists basically of five solid state subassemblies (A2 through A6), and a step motor (B1), with a counter and reset handcrank. The a-c to d-c converter A2 receives the total speed signal from amplifier AR2 in the 3A2 module. The output of converter A2 is a d-c voltage proportional to the a-c total


FROM OSS 3A1
18V/40 KNOTS 400∿
TOTAL SPEED (400∿)
OWN SHIP SPEED N-S (400∿)
OWN SHIP SPEED E-W (400∿)
A1R6
A1R5
-15V REG
AMPL AR2
B3
RX
B1
CT
B2
CT
CUTOVER NETWORK
AMPL AR1
B6
MOT
OWN SHIP COURSE
K1
B4
CDX
B5
CDX
K2
TUNING NETWORK C2
K3
TUNING NETWORK C3
TRUE BEARING 1 X (60∿ OR 400∿)
TRUE BEARING 1 X (60∿ OR 400∿)
TO NC-2 MOD 2 PLOTTING TABLE
FROM SHIP GYRO-COMPASS OR EQUIVALENT SOURCE
OWN SHIP COURSE 36 X (400∿)
OWN SHIP COURSE 1 X (400∿)
FROM NC-2 MOD 2 PLOTTING TABLE
MANUAL OWN SHIP COURSE INPUT 1 X (400∿)
MANUAL COURSE MODE SIGNAL + 30V
RELATIVE BEARING 1 X (60∿ OR 400∿)
RELATIVE BEARING (B4) 60∿ SIGNAL + 30V
RELATIVE BEARING 1 X (60∿ OR 400∿)
RELATIVE BEARING (B5) 60∿ SIGNAL + 30V
OWN SHIP COURSE MODULE
3A2
(537-301-000)

40.172

Figure 16-20.—Own ship's course module (3A2).


OWN SHIP SPEED N-S MODULE
3A3
(537-302-000)
OWN SHIP SPEED N-S
(400 ~)
A1R1
SCALE
FACTOR
ADJUST
AMPL
A1AR1
B2
MOT
B1
CX
B3
CX
R1
18V
400~
POSITION FEEDBACK
OWN SHIP SPEED N-S
10 X 10 KNOTS/360°
OWN SHIP SPEED N-S
1 X 100 KNOTS/360°
TO
EXTERNAL
EQUIPMENT

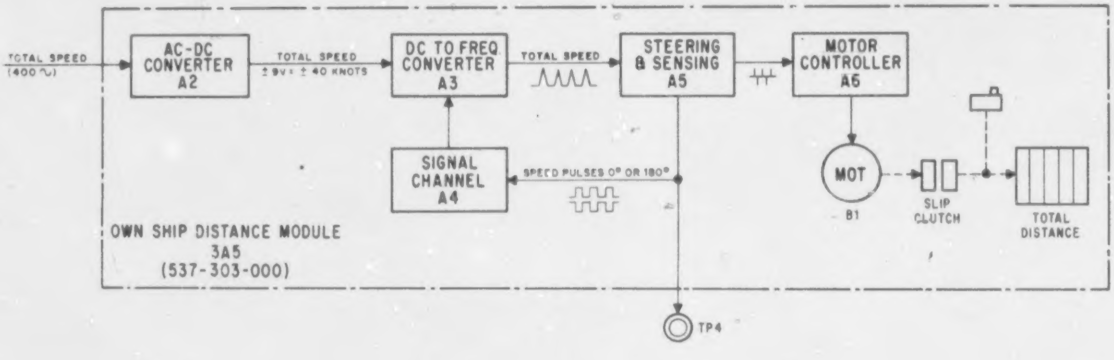
40.173

Figure 16-21. — Own ship's speed north-south module (3A3).

speed signal input. This d-c voltage is fed to the d-c To Frequency Converter A3. Within the A3 subassembly, the d-c level is converted into a sawtooth waveform whose slope is proportional to the d-c signal input. This waveform is compared to the d-c reference voltage by two comparators. The resulting waveform is a series of pulses, the frequency of which is proportional to the d-c signal input. Steering and Sensing subassembly A5 receives the pulse train from the A3 subassembly and converts it to a symmetrical square wave, which drives the Signal Channel subassembly A4. This subassembly isolates the square waves from circuit ground, and provides square wave pulses to the A3 subassembly. These square wave pulses are used by the A3 subassembly in forming the sawtooth waveform. The A5 subassembly also provides a pulse train to the Motor Controller A6. Subassembly A6 provides the step pulses to drive motor B1. Step motor B1, through a slip clutch assembly, drives the Total Distance Counter.

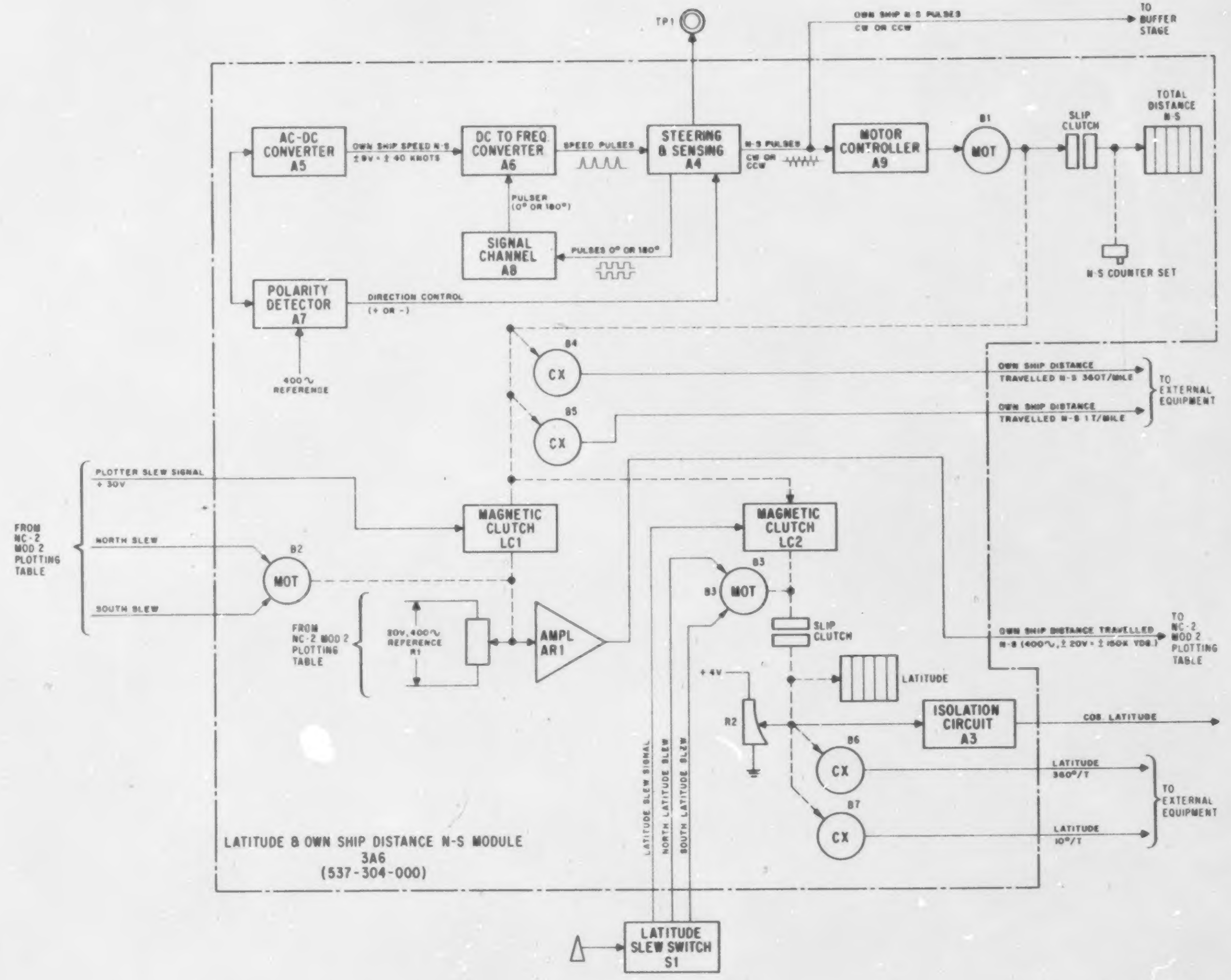
Latitude and Own Ship's Distance Module (3A6)

The Latitude and Own Ship's Distance Module (3A6) (fig. 16-23) consists of six solid state


TOTAL SPEED
(400 ~)
AC-DC
CONVERTER
A2
TOTAL SPEED
±9V = ±40 KNOTS
DC TO FREQ
CONVERTER
A3
TOTAL SPEED
STEERING
& SENSING
A5
MOTOR
CONTROLLER
A6
SIGNAL
CHANNEL
A4
SPEED PULSES 0° OR 180°
MOT
B1
SLIP
CLUTCH
TOTAL
DISTANCE
OWN SHIP DISTANCE MODULE
3A5
(537-303-000)
TP4

40.174

Figure 16-22. — Own ship's distance module (3A5).


TP1
OWN SHIP N-S PULSES
CW OR CCW
TO BUFFER STAGE
AC-DC CONVERTER A5
OWN SHIP SPEED N-S
±9V = ± 40 KNOTS
DC TO FREQ. CONVERTER A6
SPEED PULSES
STEERING & SENSING A4
N-S PULSES
CW OR CCW
MOTOR CONTROLLER A9
B1
MOT
SLIP CLUTCH
TOTAL DISTANCE N-S
N-S COUNTER SET
PULSER (0° OR 180°)
SIGNAL CHANNEL A8
PULSES 0° OR 180°
POLARITY DETECTOR A7
DIRECTION CONTROL
(+ OR -)
400∿ REFERENCE
B4
CX
B5
CX
OWN SHIP DISTANCE
TRAVELLED N-S 360T/MILE
OWN SHIP DISTANCE
TRAVELLED N-S 1T/MILE
TO EXTERNAL EQUIPMENT
FROM NC-2 MOD 2 PLOTTING TABLE
PLOTTER SLEW SIGNAL
+ 30V
NORTH SLEW
SOUTH SLEW
B2
MOT
MAGNETIC CLUTCH LC1
FROM NC-2 MOD 2 PLOTTING TABLE
20V, 400∿ REFERENCE
R1
AMPL AR1
MAGNETIC CLUTCH LC2
B3
MOT
SLIP CLUTCH
LATITUDE
+4V
R2
ISOLATION CIRCUIT A3
OWN SHIP DISTANCE TRAVELLED
N-S (400∿, ± 20V = ± 150K YDS.)
TO NC-2 MOD 2 PLOTTING TABLE
COS LATITUDE
B6
CX
B7
CX
LATITUDE
360°/T
LATITUDE
10°/T
TO EXTERNAL EQUIPMENT
LATITUDE SLEW SIGNAL
NORTH LATITUDE SLEW
SOUTH LATITUDE SLEW
LATITUDE SLEW SWITCH S1
LATITUDE & OWN SHIP DISTANCE N-S MODULE
3A6
(537-304-000)

40.175

Figure 16-23. — Latitude and own ship's distance north-south module (3A6).

subassemblies (A4 through A9) and various rotation devices, such as control transmitters and servomotors. Subassemblies A4, A5, A6, A8, and A9 function much like those in the 3A5 module. Unless specifically noted, the operation will be considered identical. A Polarity Detector A7 is needed to sense the phase of the input signal from resolver B3 in the 3A2 module, since module 3A6 must integrate in both the north and south coordinates (that is, the integrater must provide clockwise and counterclockwise pulses to motor B1). Polarity Detector A7 senses the signal input phase and sends a signal to subassembly A4 to set up the bidirectional pulses to motor B1. Subassembly A4 also provides clockwise and counterclockwise pulses to the 3A9 module. Control transmitters B4 and B5 supply external equipment with own ship's distance (OSD) traveled N-S synchro data. Control transformers B6 and B7 supply external equipment with latitude synchro data. B2 and B3 are slew motors used for resetting the latitude counter and the slider of potentiometer R1. LC1 and LC2 are magnetic clutch assemblies used when slewing. The slider of potentiometer R1 picks off a signal which is fed through amplifier AR1 to supply own ship's distance (OSD) N-S traveled to the Plotting Table. Potentiometer R2 and isolation circuit A3 provide cosine of the latitude information to module 3A7. This information is used in the 3A7 module to compensate for varying distances between lines of longitude at different latitudes. The distance between lines of latitude is 60 nautical miles. The distance between lines of longitude varies, being 60 nautical miles at the Equator and decreasing with an increase in latitude, either north or south. At 60° latitude the distance between longitude lines is 30 nautical miles.

Longitude and Own Ship's Distance E-W Module (3A7)

The Longitude and Own Ship's Distance E-W Module (3A7) (fig. 16-24) contains two functional channels. One channel computes longitude and the other computes own ship's distance traveled E-W. The longitude channel of the 3A7 module is similar to the latitude module 3A6, except that its d-c To Frequency Converter A8 accepts the cosine input from the 3A6 module. The two channels share a common a-c to d-c converter A11. Otherwise, the two channels operate independent of each other. Since the solid state subassemblies in the 3A7 basically operate the same as those in the 3A5 and 3A6 modules, they will not be discussed.

In the longitude channel, control transmitters B7 and B8 transmit longitude synchro data to external equipment. The longitude counter gives a direct readout of ship's longitude. Slew switch S2, slew motor B6, and magnetic clutch LC2 are used to reset the longitude counter and both B7 and B8.

In the own ship's distance E-W channel, control transmitters B2 and B4 transmit own ship's distance E-W data to external equipment. The total distance E-W counter gives a direct readout of total E-W distance traveled. The slider of potentiometer R1 picks off a signal which is fed through amplifier AR1 to supply OSD E-W to the Plotting Table. Slew motor B3 and magnetic clutch LC 1 are used to reset the slider of potentiometer R1. Steering and Sensing subassembly A4 supplies clockwise and counterclockwise pulses to the 3A8 module.

Solid-State Step Transmitter Modules (3A8 and 3A9)

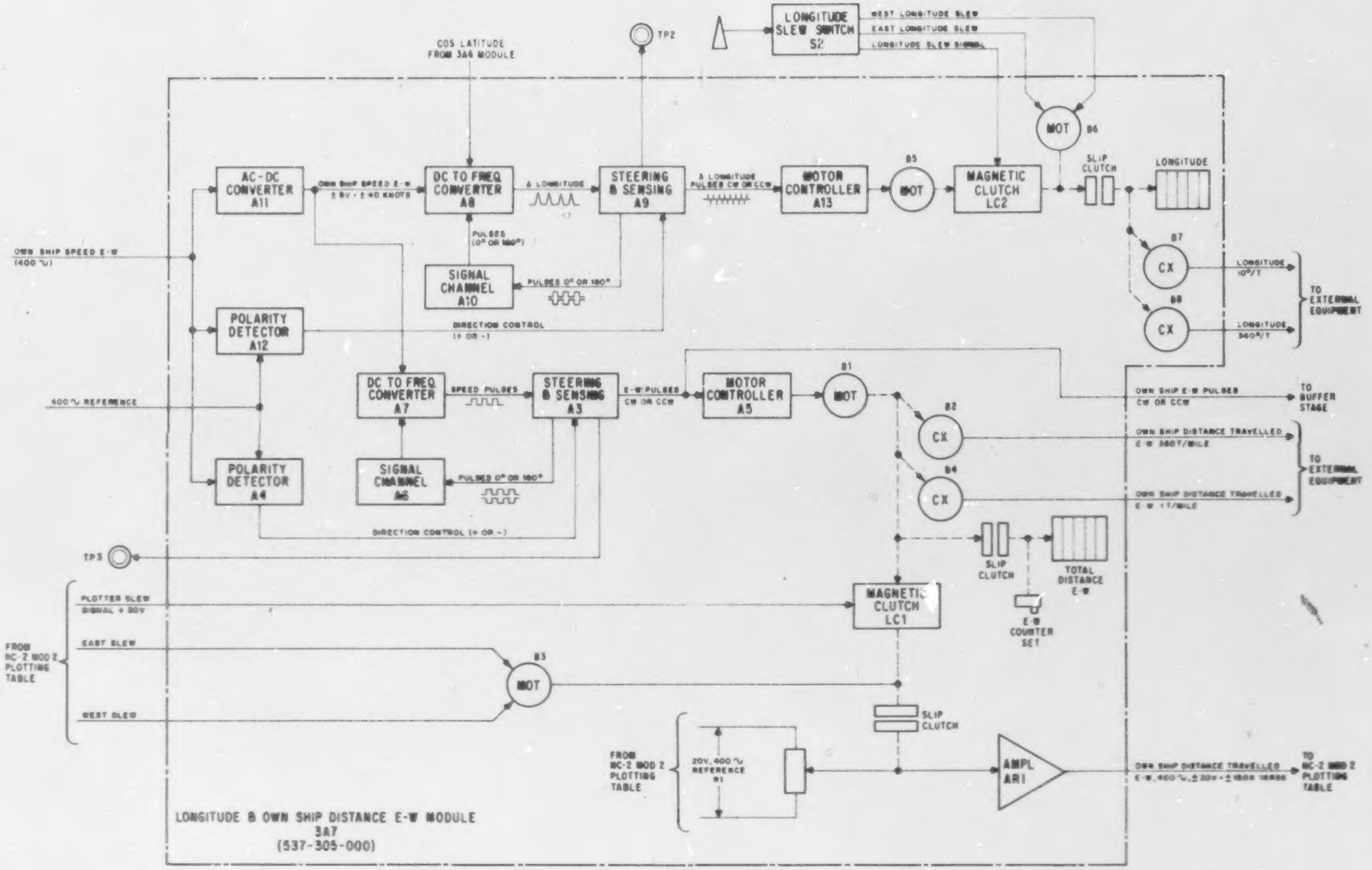
The two Solid-State Step Transmitter Modules (3A8 and 3A9) (fig. 16-25) are identical and interchangeable. The 3A8 module provides N-S step transmitter data and the 3A9 provides E-W step transmitter data to external equipment. Each is an electronic module, which accepts a pulse train input from either the 3A6 or 3A7 module (distance integrator). The pulse train originates in the corresponding steering and sensing subassembly. This pulse train frequency is the same as that sent to the motor controller subassembly in the 3A6 or 3A7 module. When fed into the Solid-State Step Transmitter module, it triggers the module to provide step outputs to remote equipment.

Subassemblies 3A10 through 3A14 consist of the various power supplies, transformer trim assemblies, and the reference voltage assemblies required by the DRAI.

Summary of Functions

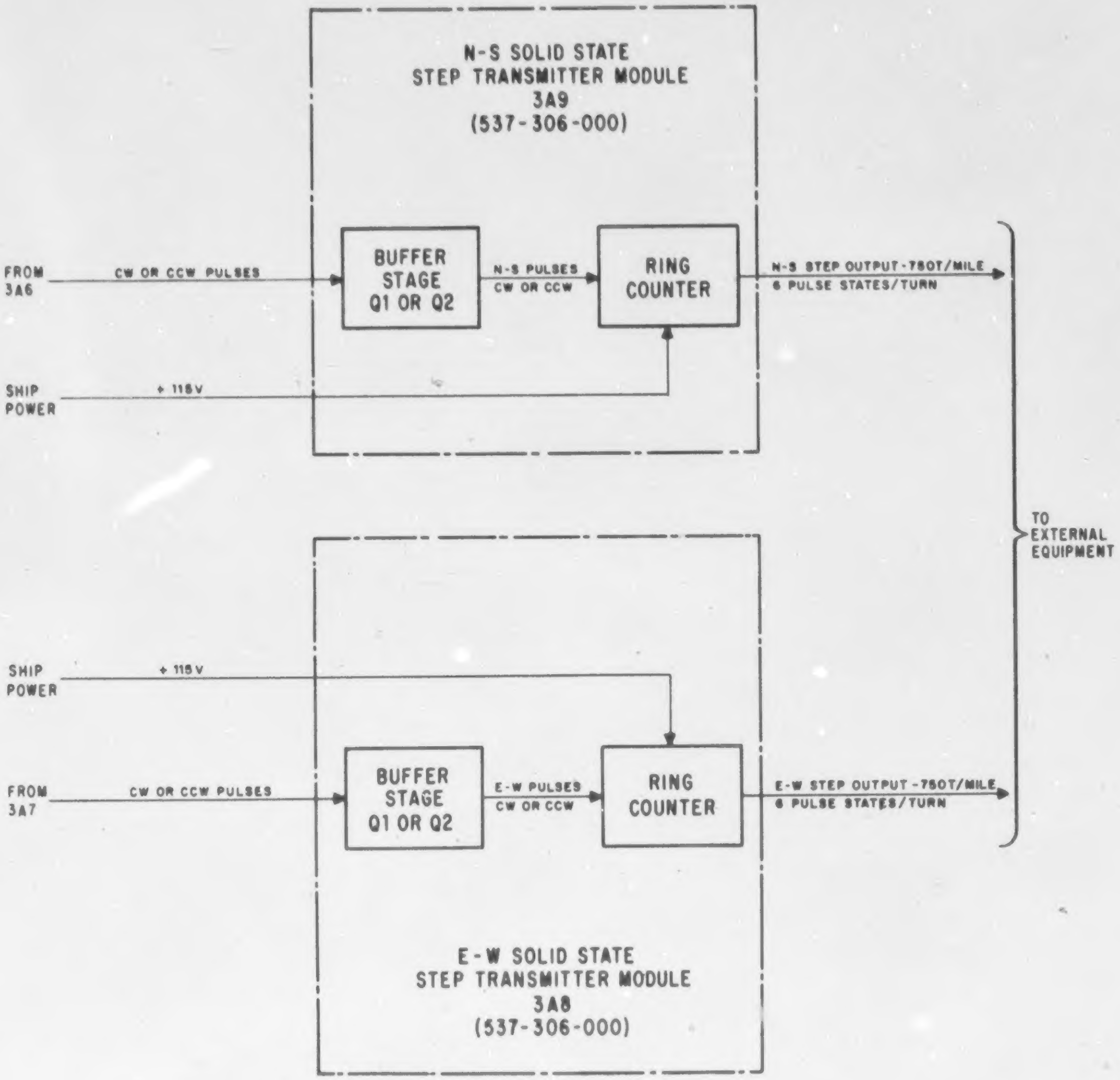
The dead reckoning analyzer indicator (fig. 16-26) when used in conjunction with the plotting table provides a counter indication of the ship's position in terms of latitude and longitude, total distance traveled, total distance east-west, total distance north-south, and ship's heading.

Own ship's speed module provides a means to select OSS automatically, either from the underwater log or a manual input representing ship's speed. This signal is fed to the OSC module which receives OSC from the ship's


LONGITUDE SLEW SWITCH S2
WEST LONGITUDE SLEW
EAST LONGITUDE SLEW
LONGITUDE SLEW SIGNAL
TP2
COS LATITUDE FROM 3A6 MODULE
AC-DC CONVERTER A11
OWN SHIP SPEED E-W 2 8V - ±40 KNOTS
DC TO FREQ CONVERTER A8
Δ LONGITUDE
STEERING & SENSING A9
Δ LONGITUDE PULSES CW OR CCW
MOTOR CONTROLLER A13
B5
MOT
MAGNETIC CLUTCH LC2
MOT
B6
SLIP CLUTCH
LONGITUDE
PULSES (0° OR 180°)
SIGNAL CHANNEL A10
PULSES 0° OR 180°
OWN SHIP SPEED E-W (400 ∿)
POLARITY DETECTOR A12
DIRECTION CONTROL (+ OR -)
B7
CX
LONGITUDE 10°/T
B8
CX
LONGITUDE 360°/T
TO EXTERNAL EQUIPMENT
400 ∿ REFERENCE
DC TO FREQ CONVERTER A7
SPEED PULSES
STEERING & SENSING A3
E-W PULSES CW OR CCW
MOTOR CONTROLLER A5
B1
MOT
OWN SHIP E-W PULSES CW OR CCW
TO BUFFER STAGE
B2
CX
OWN SHIP DISTANCE TRAVELLED E-W 360T/MILE
B4
CX
OWN SHIP DISTANCE TRAVELLED E-W 1T/MILE
TO EXTERNAL EQUIPMENT
POLARITY DETECTOR A4
SIGNAL CHANNEL A6
PULSES 0° OR 180°
DIRECTION CONTROL (+ OR -)
TP3
SLIP CLUTCH
TOTAL DISTANCE E-W
E-W COUNTER SET
MAGNETIC CLUTCH LC1
PLOTTER SLEW SIGNAL + 30V
EAST SLEW
WEST SLEW
FROM RC-2 MOD 2 PLOTTING TABLE
B3
MOT
SLIP CLUTCH
FROM RC-2 MOD 2 PLOTTING TABLE
20V, 400 ∿ REFERENCE R1
AMPL AR1
OWN SHIP DISTANCE TRAVELLED E-W, 400 ∿, ±20V = ±1800 YARDS
TO RC-2 MOD 2 PLOTTING TABLE
LONGITUDE & OWN SHIP DISTANCE E-W MODULE
3A7
(537-305-000)

40.176

Figure 16-24.—Longitude and own ship's distance east-west module (3A7).

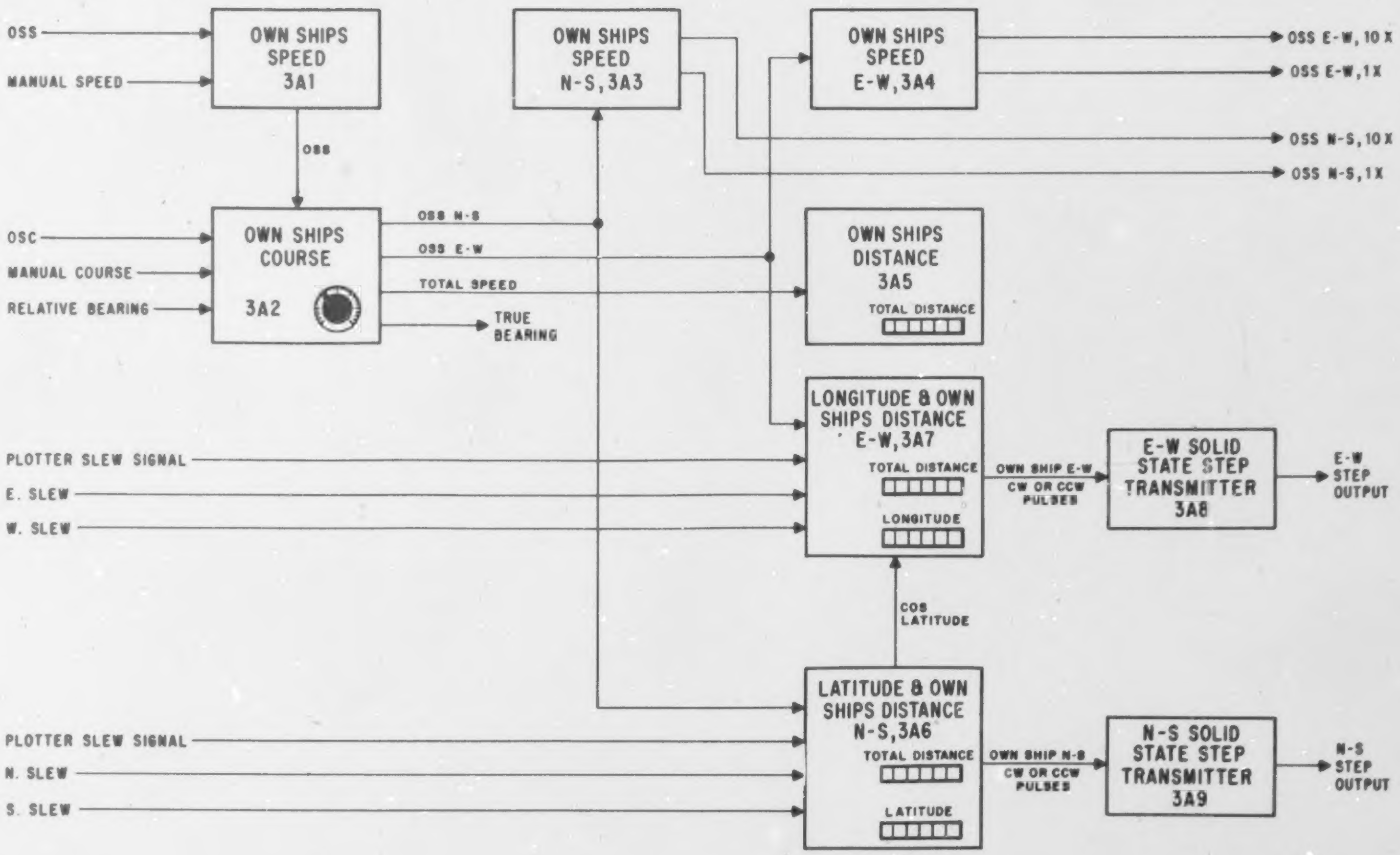

N-S SOLID STATE
STEP TRANSMITTER MODULE
3A9
(537-306-000)
FROM 3A6
CW OR CCW PULSES
BUFFER STAGE Q1 OR Q2
N-S PULSES CW OR CCW
RING COUNTER
N-S STEP OUTPUT-750T/MILE
6 PULSE STATES/TURN
SHIP POWER
+ 115V
TO EXTERNAL EQUIPMENT
SHIP POWER
+ 115V
FROM 3A7
CW OR CCW PULSES
BUFFER STAGE Q1 OR Q2
E-W PULSES CW OR CCW
RING COUNTER
E-W STEP OUTPUT-750T/MILE
6 PULSE STATES/TURN
E-W SOLID STATE
STEP TRANSMITTER MODULE
3A8
(537-306-000)

40.177

Figure 16-25. — E-W solid-state step transmitter module (3A8).

gyro or a manual course input. It also receives a relative bearing input from the plotting table and converts this input to true bearing for transmission back to the plotting table. The N-S and E-W ship's speed components are fed to own ship's speed N-S module, own ship's speed E-W module, longitude and own ship's distance E-W module, and latitude and own ship's distance N-S modules. The total ship's speed output is fed directly to own ship's speed module which provides a counter readout of total own ship's distance traveled.

The own ship's speed N-S and own ship's speed E-W modules function to provide external


OSS
MANUAL SPEED
OWN SHIPS SPEED 3A1
OSS
OSC
MANUAL COURSE
RELATIVE BEARING
OWN SHIPS COURSE 3A2
OSS N-S
OSS E-W
TOTAL SPEED
TRUE BEARING
OWN SHIPS SPEED N-S, 3A3
OWN SHIPS SPEED E-W, 3A4
OSS E-W, 10 X
OSS E-W, 1 X
OSS N-S, 10 X
OSS N-S, 1 X
OWN SHIPS DISTANCE 3A5
TOTAL DISTANCE
PLOTTER SLEW SIGNAL
E. SLEW
W. SLEW
LONGITUDE & OWN SHIPS DISTANCE E-W, 3A7
TOTAL DISTANCE
LONGITUDE
OWN SHIP E-W
CW OR CCW PULSES
E-W SOLID STATE STEP TRANSMITTER 3A8
E-W STEP OUTPUT
COS LATITUDE
PLOTTER SLEW SIGNAL
N. SLEW
S. SLEW
LATITUDE & OWN SHIPS DISTANCE N-S, 3A6
TOTAL DISTANCE
LATITUDE
OWN SHIP N-S
CW OR CCW PULSES
N-S SOLID STATE STEP TRANSMITTER 3A9
N-S STEP OUTPUT

40.178

Figure 16-26.—DRAI Mk 9 Mod 0 or 2.

equipment with two speed signals representing N-S and E-W and own ship's speed. The longitude and own ship's distance E-W module receives its input from the own ship's course module in the form of an OSS E-W signal. This signal is converted into clockwise and counterclockwise pulses to correspond to the east or west coordinates of the input signal. This output is fed to the E-W Solid-State Step Transmitter which provides step outputs to remote equipment (Plotting Table). This module also receives a signal corresponding to the cosine of the local latitude.

The latitude and Own Ship's Distance N-S module receives its input from the N-S OSS signal of the own ship's course module. This signal is converted into clockwise and counterclockwise pulses to correspond to the north or south coordinate of the input signal. This output is fed to the N-S Solid-State Step Transmitter which provides step outputs to remote equipment (Plotting Table). The latitude and Own Ship's Distance N-S module provides a signal, which corresponds to the cosine of latitude, to the longitude and Own Ship's Distance E-W module.

PLOTTING TABLE NC-2 MOD 2

The Plotting Table is capable of graphically plotting own ship's position and four air, surface, or underwater targets on the plotting surface. In addition, a relative plot mode of operation is provided. In relative plot, the own ship's position, which is the center of the polar diagram (fig. 16-27), remains stationary and the four targets are plotted relative to own ship's position. The Target Plot Attachments (TPA) position the four target symbols. Each TPA operates independent of the other TPAs. Two types of target symbols and four colors (red, green, yellow, and orange) are used to distinguish the individual TPAs. The yellow and orange TPAs are projected on the plotting surface as circles of light approximately 1/8 of an inch in diameter. The red and green TPAs are projected on the plotting surface as crosses of light with a spot marking the center of each cross. The red and green TPAs are each provided with a cursor (fig. 16-27) which is a variable line of light extending from one leg of the cross (target symbol). The cursor is used to obtain range and bearing information between targets and/or own ship. Cursor operation is manually controlled by the operator. When the cursor is manually operated to indicate zero range, only the target cross symbol is visual on the plotting surface.

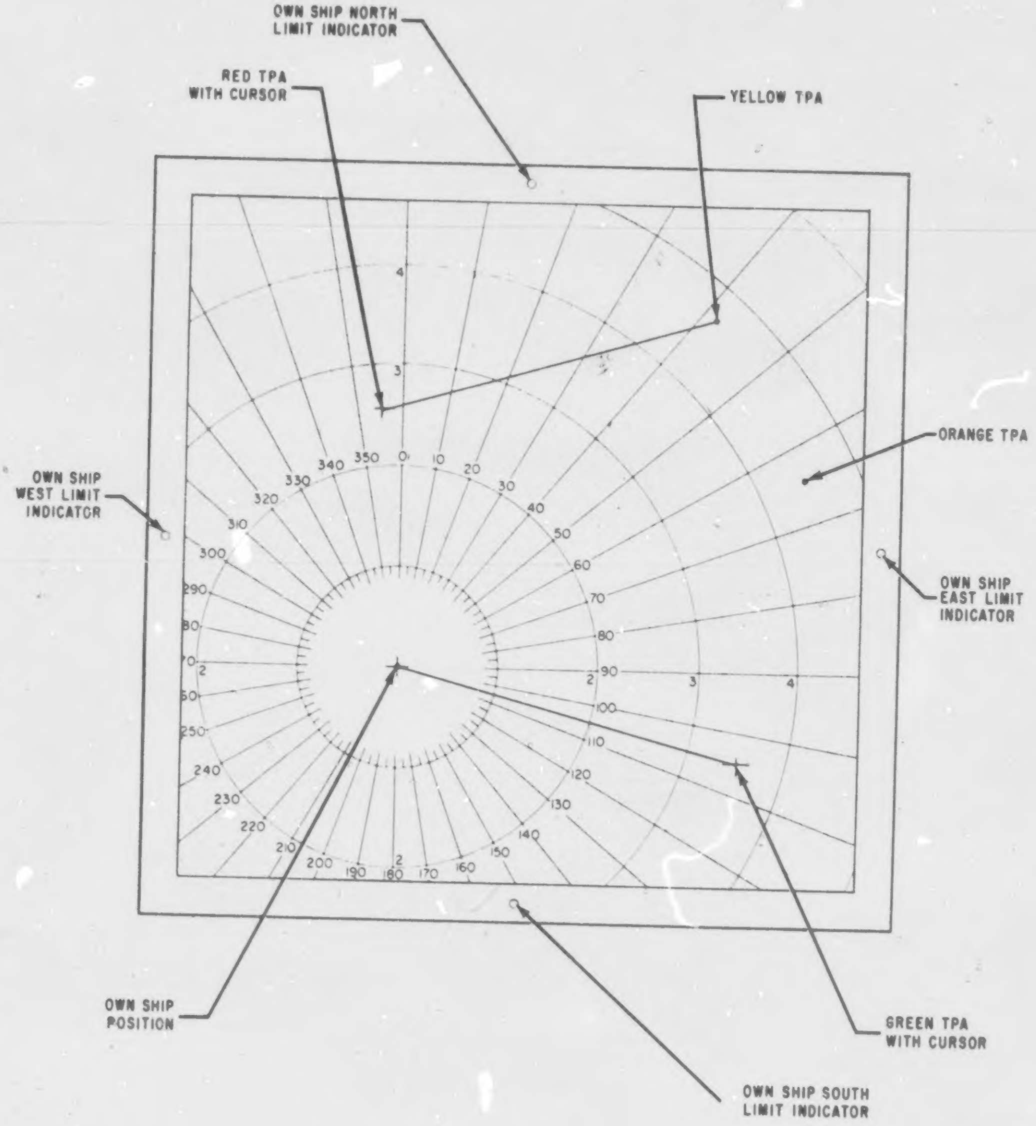
The visual display can be projected in eight different scales. The selected scale determines the miles or yards per inch presentation of the display. Each scales are provided: 200 yd/in., 500 yd/in., 1/25,000, 1000 yd/in., 1/50,000, 1 mi/in., 2.5 mi/in., and 5 mi/in. During scale changes, cursor length automatically varies to remain superimposed on the targets, provided their maximum length of 20 inches is not exceeded.

Functional Description

The functional description of the plotting table is covered in two parts. The first part consists of the data and major components that affect own ship's position; the second part covers TPA plot. No attempt is made to give a complete analysis of the system. For specific operation, the manufacturer's technical manual for the plotter should be consulted.

OWN SHIP'S POSITION. — The own ship's position is represented by the center of the polar diagram (fig. 16-27). The polar diagram is projected on the plotting surface by the own ship's projector. The position of this projector is controlled by two lead screws which are rotated by the N-S and E-W servo loops (fig. 16-28).

The N-S servo loop receives N-S own ship's distance data from the 3A6 module in the DRAI. The data is fed to a summing amplifier which operates much like a conventional servoamplifier. The output of the summing amplifier drives motor B1. In driving, motor B1 positions the N-S lead screw and the slider of potentiometer R1. The voltage picked off by the slider of R1 is 180 degrees out of phase with the input signal. This voltage is fed back to the input of the summing amplifier to cancel the input signal. Scale selection is accomplished by changing the excitation voltage to potentiometer R1. The E-W and N-S servo loops function in the same way except that the E-W loop receives own ship's distance E-W data from the 3A7 module in the DRAI. Four limit lights are provided to indicate when the polar diagram has moved off the plotting surface (no longer visible). These lights are installed in the N-S and E-W plane. The own ship's projector lamp is extinguished when the own ship's projector nears a mechanical stop. Own ship's projector slewing circuits are provided to return the polar diagram to a new

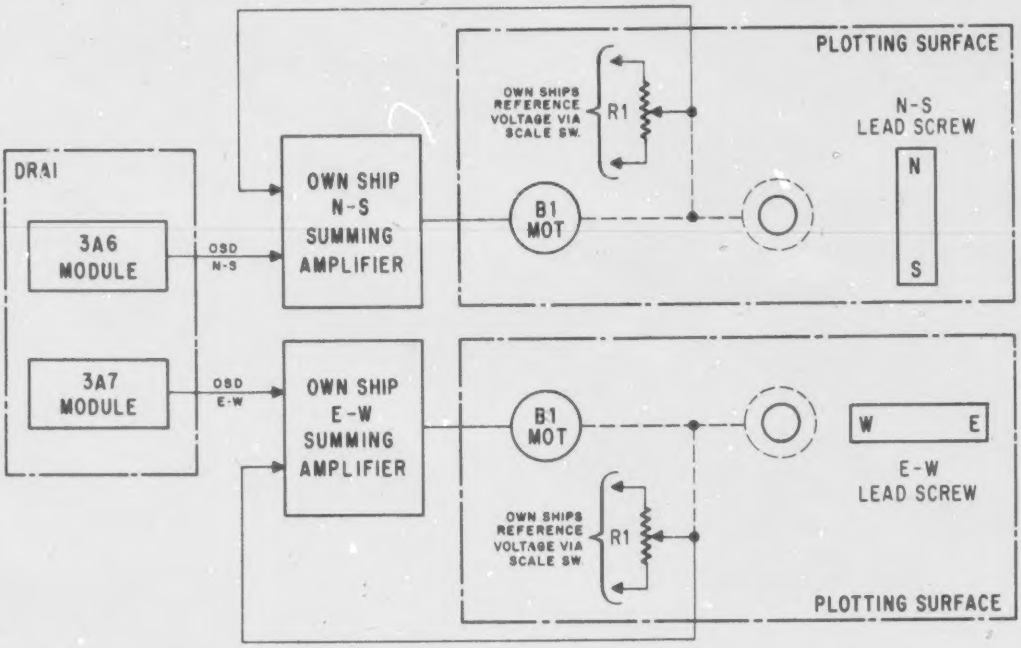

OWN SHIP NORTH LIMIT INDICATOR
RED TPA WITH CURSOR
YELLOW TPA
ORANGE TPA
OWN SHIP WEST LIMIT INDICATOR
OWN SHIP EAST LIMIT INDICATOR
OWN SHIP POSITION
GREEN TPA WITH CURSOR
OWN SHIP SOUTH LIMIT INDICATOR
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
2
3
4

40.179

Figure 16-27.—View of plotting surface with polar projection, and typical TPA presentations.

starting point. When the own ship's projector is slewed out of the stops toward the center of the plotting surface, the respective limit light is extinguished and the projector lamp is lighted.

TPA POSITION SERVO.—Each of the four TPA positioning servo systems functions in essentially the same manner, except that, in the red and green channels, cursors are added to the TPA symbol along with the circuitry required to manually insert range and bearing data. The data switching panel (fig. 16-29) determines the mode of operation of the TPAs. Only the radar and the sonar mode are discussed.


PLOTTING SURFACE
OWN SHIPS REFERENCE VOLTAGE VIA SCALE SW.
R1
N-S LEAD SCREW
N
S
DRAI
3A6 MODULE
OSD N-S
OWN SHIP N-S SUMMING AMPLIFIER
B1 MOT
3A7 MODULE
OSD E-W
OWN SHIP E-W SUMMING AMPLIFIER
B1 MOT
W
E
E-W LEAD SCREW
OWN SHIPS REFERENCE VOLTAGE VIA SCALE SW
R1
PLOTTING SURFACE

40.180

Figure 16-28.—Own ship's position servo.

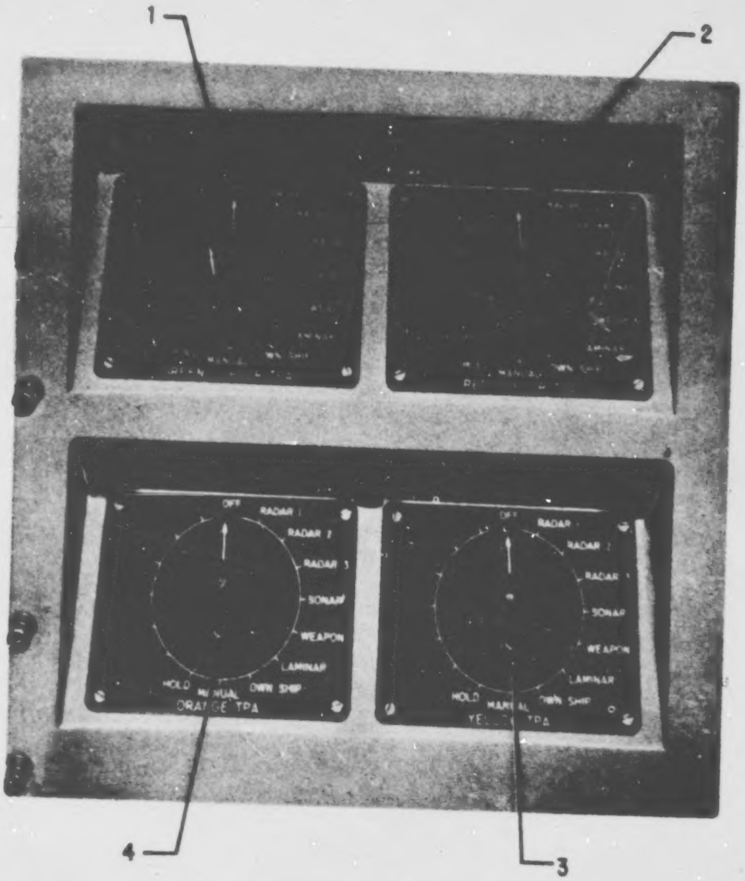
RADAR AND SONAR TRACKING FUNCTIONS.—The tracking inputs from external radar and sonar equipments are 60-Hz or 400-Hz synchro inputs, which must be converted into N-S and E-W TPA position signals (fig. 16-30). The conversion is effected by converting the 2-speed range synchro input into a TPA position voltage with a scale factor of 20 volts per 72,000 yards. The required calculations are performed in the four TPA range modules. The resulting TPA position voltage from each range module is then converted to N-S and E-W TPA position voltage in the associated TPA bearing module at a scale factor of 20 VAC per 72,000 yards. When applied to a selected pair of summing amplifiers, the N-S and E-W TPA position signals result in servo positioning of the TPA symbols.

The range servo in the TPA range module receives synchro data from radar or sonar. The range servo is a conventional control transformer closed servo loop. In driving the input signal to null, motor B3 positions the slider of potentiometer R1. The slider of R1 picks off a voltage that is used to excite the stator of resolver B3 in the TPA bearing module.

The bearing servo in the TPA bearing module receives bearing data from radar or sonar. The bearing servo is also a conventional control transformer closed servo loop. In driving the input signal to null, motor B1 mechanically positions the rotor of resolver B3.

Resolver B3 resolves the range and bearing inputs into TPA N-S and E-W position signals. Since both summing amplifiers function in the same way, only the N-S summing amplifier is discussed.

The N-S TPA position summing amplifier receives the TPA N-S signal from resolver B3 and own ship's distance N-S signal from the 3A6 module in the DRAI. These signals are summed in a resistor network. The composite signal from the resistor network is then amplified by the summing amplifier. The output of the summing amplifier drives motor B1 which, in driving, positions the TPA N-S lead screw and the slider of potentiometer R1. The voltage picked off by R1 is fed back to the input of the summing amplifier to cancel the



1. GREEN CURSOR TPA SELECTOR SWITCH
2. RED CURSOR TPA SELECTOR SWITCH
3. YELLOW TPA SELECTOR SWITCH
4. ORANGE TPA SELECTOR SWITCH

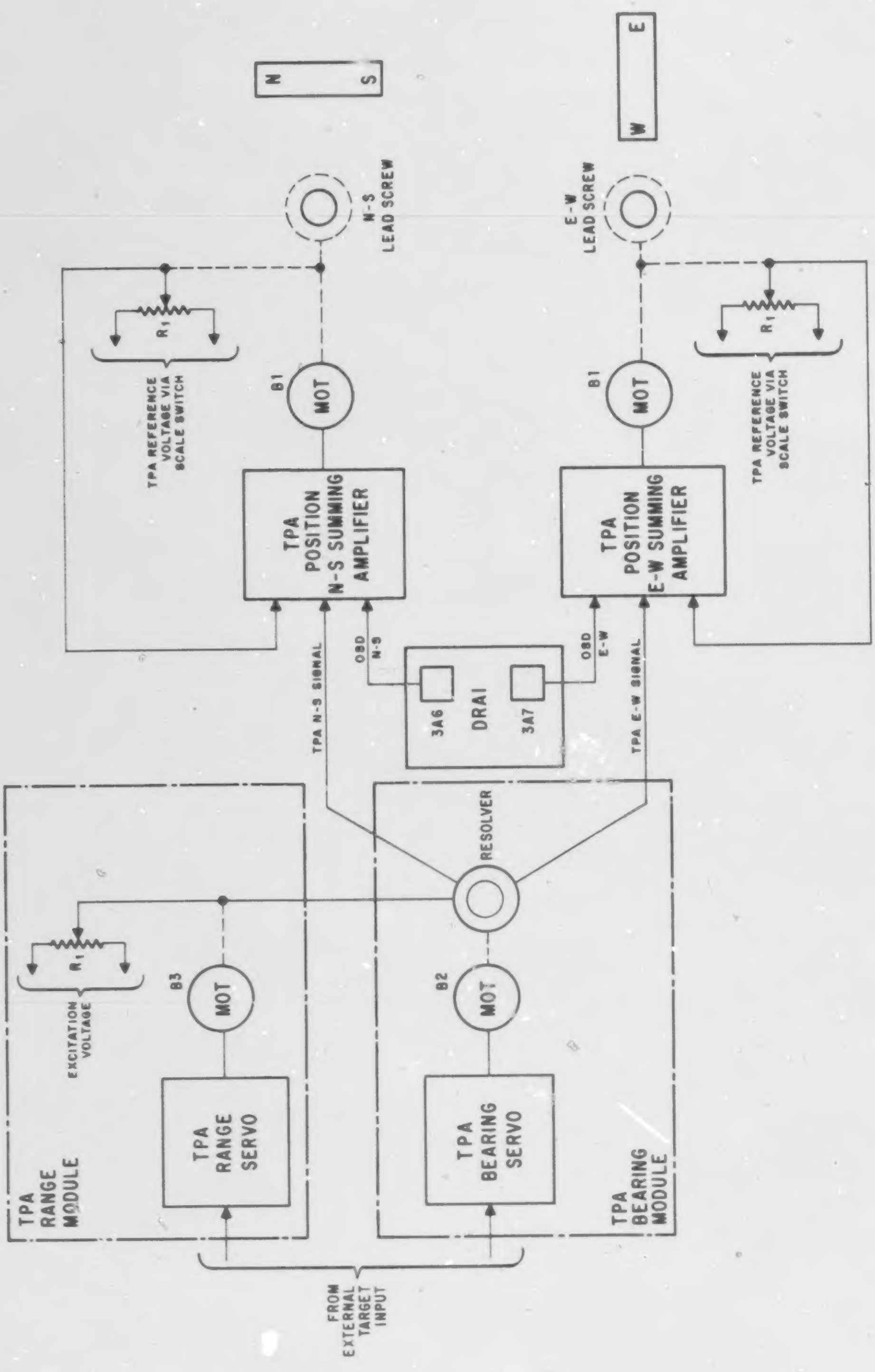
74.28(40D)B

Figure 16-29. — Data switching panel 1A9 controls and indicators.

input signal. Scale selection is accomplished by changing the excitation voltage to potentiometer R1.

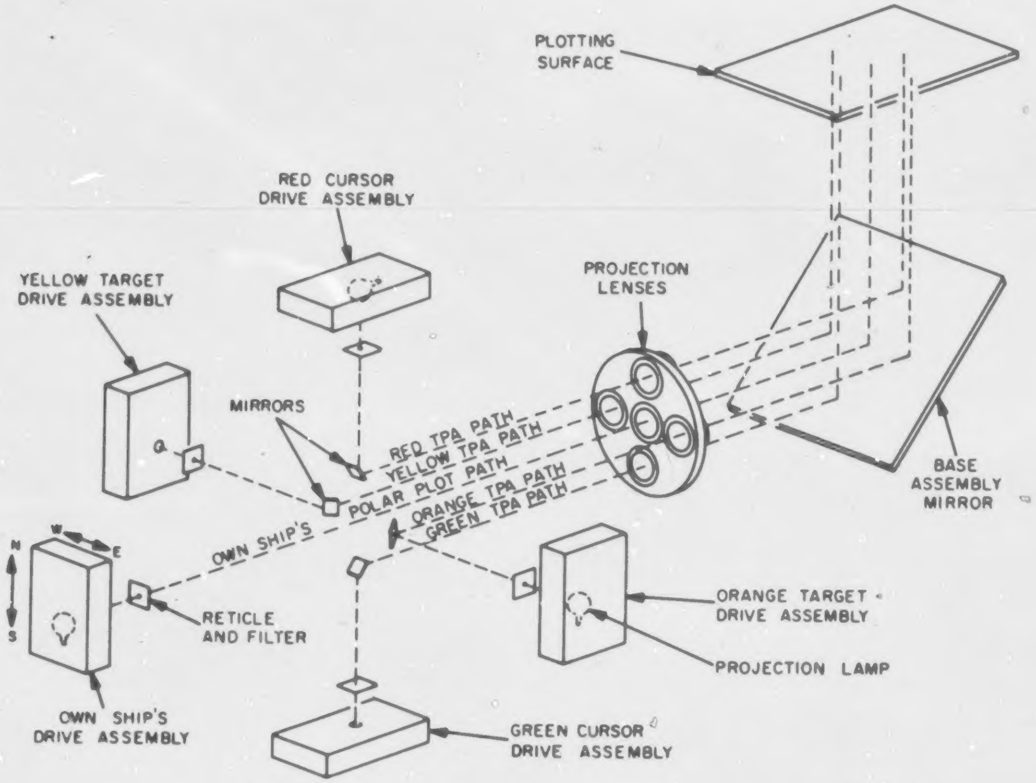
Optical System

The heart of the projection system (fig. 16-31) is the five independently moveable-drive assemblies that are mounted radially in the projector assembly. The projected image from each drive assembly is focused on the large base assembly mirror, which causes an enlarged image to be imposed on the plotting glass. The base mirror is equipped with three leveling screws to permit the mirror to be adjusted to change the magnification ratio and the positioning of the projected images. In practical applications, the leveling screws are used to adjust the range ring diameters of the own ship's polar plot; alignment and focus of the four other


TPA RANGE MODULE
TPA RANGE SERVO
MOT
B3
R1
EXCITATION VOLTAGE
TPA BEARING MODULE
TPA BEARING SERVO
MOT
B2
RESOLVER
FROM EXTERNAL TARGET INPUT
TPA N-S SIGNAL
TPA E-W SIGNAL
DRAI
3A6
3A7
OSD N-S
OSD E-W
TPA POSITION N-S SUMMING AMPLIFIER
TPA POSITION E-W SUMMING AMPLIFIER
MOT
B1
MOT
B1
R1
TPA REFERENCE VOLTAGE VIA SCALE SWITCH
R1
TPA REFERENCE VOLTAGE VIA SCALE SWITCH
N-S LEAD SCREW
E-W LEAD SCREW
N
S
W
E

40.181

Figure 16-30. — TPA position servo.


PLOTTING SURFACE
RED CURSOR DRIVE ASSEMBLY
YELLOW TARGET DRIVE ASSEMBLY
PROJECTION LENSES
MIRRORS
RED TPA PATH
YELLOW TPA PATH
POLAR PLOT PATH
ORANGE TPA PATH
GREEN TPA PATH
OWN SHIP'S
BASE ASSEMBLY MIRROR
N
W
E
S
RETICLE AND FILTER
ORANGE TARGET DRIVE ASSEMBLY
PROJECTION LAMP
OWN SHIP'S DRIVE ASSEMBLY
GREEN CURSOR DRIVE ASSEMBLY

40.145

Figure 16-31.—Optical system.

images can be accomplished by means of adjustments on the individual drive assemblies. Optically, the five projectors are essentially identical with the exception of the reticles and filter colors. Light originating from the projection lamp passes through the condensing lens, through the reticle, through the focusing lens, and through the filter, onto the main mirror and is reflected onto the plotting surface.

Comparison of Other Mods of Mk NC-2 Plotters

There are more Mk NC-2 Mod 2 plotting systems in the fleet than all of the other mods. However, the following material gives a brief summary of the capabilities of the other modifications that may be encountered.

NC-2 MOD O PLOTTER.—The NC-2 Mod 0 consists of three major components: a Dead Reckoning Indicator (DRI), plotting table, and data converter. The plotting system can graphically plot own ship's position and two air, surface, or underwater targets on the plotting table. This system also provides a continuous latitude and longitude counter readout to indicate the ship's geographical position. The DRI is an electromechanical computer which receives the N-S and E-W speed component signal from the plotting table and computes this data into latitude and longitude, indicating the ship's geographical position. The data converter receives range and speed inputs from radar, sonar, and the underwater log and converts this data into signals that can be used by the plotting table.

NC-2 MOD 1/1A PLOTTER.—The NC-2 Mod 1/1A consists of two major units: a bulkhead-mounted Dead Reckoning Indicator (DRI) and a deck-mounted plotting table. The plotting system can graphically plot own ship's position and four air, surface, or underwater targets on the plotting surface. This system also provides a continuous latitude and longitude counter readout to indicate the ship's geographical position. The DRI is an electromechanical computer which receives inputs from the underwater log and gyrocompass and computes latitude and longitude. The DRI also resolves ship's speed and course into N-S and E-W speed components which are fed to the plotting table.

NC-2 MOD 3 PLOTTER.— The NC-2 Mod 3 (PT 512/S Plotter) incorporates new concepts not found in the NC-2 Mod 2 or 2A. Extensively redesigned, the plotting system is actually an upgrading of the NC-2 Mod 2A though a great deal of similarity can be found in their operation.

The Mod 3, like other plotting systems, is used for plotting own ship's position and as many as four positions for surface, air, or underwater targets. Unlike the previous systems, the Mod 3 is a single unit system. It receives synchro speed and course data from the underwater log and gyrocompass, and converts the data into analog signals which position the own ship's display. The TPAs receive their inputs through a selector switch that enables the operator to select any of nine target range and bearing inputs.

Training

Schools are available for training personnel to maintain the NC-2 plotters. Formal classes are conducted in Norfolk and San Diego for the following types of plotters: Mk NC-2 Mod 0 (MARSLAND), Mk NC-2 Mod 1/1A (SPERRY), Mk NC-2 Mod 2/2A (HUYCK) and Mk NC-2 Mod 3 (HARTMAN). Onboard training is conducted by mobile technical units on each coast. The equipment is presently of such a sophisticated nature that this training is invaluable and maximum use should be made of available facilities.

Maintenance

Maintenance should be carried out in accordance with specific instructions. Special test equipments designated in the manufacturer's technical manual and step-by-step procedures listed in tables for each of the units will help the IC Electrician to quickly diagnose and correct a fault and return the equipment to its normal working order.

CHAPTER 17

MAINTENANCE

The purpose of maintenance is to ensure that the equipment you are responsible for is ready for service at all times. The effectiveness of your equipment depends largely upon the case and attention you give it. An improperly adjusted synchro amplifier, for example, can reduce the accuracy of each piece of equipment it supplies an input to.

The work you perform on equipment falls into two broad categories: (1) PREVENTIVE maintenance or actions you take to reduce or eliminate failure and prolong the useful life of your equipment, and (2) CORRECTIVE maintenance or actions you taken when a part or component has failed and the equipment is out of service.

In maintenance work of any type, you must use knowledge and skills of two fundamental kinds. First, you must have SPECIFIC information which applies only to the particular equipment which you may be called upon to repair or keep in good condition. This information consists of special procedures and processes, and detailed step-by-step directions used to maintain a particular piece of equipment, and is provided by the Planned Maintenance Subsystem of the 3-M System, the Naval Ship Systems Command, fleet commanders, or type commanders. Second, you must possess and use certain GENERAL skills and knowledge which apply to many kinds of equipment and to many types of work assignments. These skills are learned on the job, whereas the basic knowledge factors or principles can be acquired through study of textual materials, such as rate training manuals.

PREVENTIVE AND CORRECTIVE MAINTENANCE

If you have ever owned a car or in some way have had a share of the responsibility of car ownership, undoubtedly you found out that there is more to owning a car than simply driving it. The car has to be washed and waxed to prevent deterioration, and lubricated to reduce wear. Periodically, the brakes must be adjusted, the sparkplugs cleaned, the timing checked, the fluid levels and tire pressures measured, etc. If you faithfully follow a good PREVENTIVE maintenance routine, it is unlikely that your car will be laid up for long repair periods. The same line of reasoning applies to interior communications equipment. In many instances, the failure of the part or component that caused an equipment malfunction or casualty can be traced to improper preventive maintenance. The sole purpose of preventive maintenance is to stop trouble before it starts.

Preventive maintenance consists of the care, upkeep, and minor repairs and adjustments performed to ensure the best condition of the equipment to reduce the chance of sudden equipment failure or malfunction. It involves four major types of activity:

1. Cleaning
2. Lubrication
3. Inspection
4. Checking performance

When preventive maintenance or performance checks reveal that a casualty or malfunction exists in a system or equipment, some form of corrective maintenance is required. Corrective maintenance includes those activities required to restore IC equipment to its designed capabilities or efficiency. This includes the repair of damage caused by wear, accident, or other cause.

Corrective maintenance is generally performed in three phases: (1) troubleshooting, (2) removal and replacement of parts, and (3) alignment and adjustment. Occasionally there is an overlap of some of the activities of preventive and corrective maintenance.

CARE AND UPKEEP OF IC EQUIPMENT

The care and upkeep of equipment includes ways and means of cleaning and lubricating the equipment or protecting it against the effects of dust, dirt, moisture, wear, etc.

CLEANING PRACTICES

Loose dust, dirt, or lint can best be removed by a vaccum cleaner, or by wiping with clean rags. Low pressure air may be used provided that the air is free from foreign particles and moisture, and that the air pressure is sufficiently reduced to preclude damage to the equipment. Compressed air should be used with caution if abrasive or metal particles are present as the particles may be driven into the insulation and air gaps.

Solvents

Oil and hard deposits of dirt or other foreign matter can be removed with a cloth dampened with an approved cleaning solvent. Inhibited methyl chloroform and trichloroethylene are approved solvents. Trichloroethylene should not be used to clean insulation because of its strong solvent action. Inhibited methyl chloroform may be used to clean insulation and parts painted with insulating varnish if it is used sparingly.

If allowed to stand on an insulating varnish, inhibited methyl chloroform is likely to dissolve the varnish. Therefore, before using this solvent, try it on a small area or sample of the insulating material to determine its effect. As much as practicable, avoid the use of cleaning solvents because of their corrosive action, harmful effect on insulating materials, risk of fire, and toxicity, in particular. In choosing a solvent for cleaning equipment, follow the instructions in the manufacturer's technical manual or the label on the solvent container and the maintenance requirements card, taking in account the risk of fire and the need for adequate ventilation.

To clean insulation or parts painted with insulating varnish, slightly dampen a lintless cloth or piece of surgical gauze with inhibited methyl chloroform and lightly rub the surfaces to be cleaned. Allow the surfaces to dry and repeat the process as necessary. After cleaning, wipe the surfaces with a clean dry cloth.

When using either inhibited methyl chloroform or trichloroethylene, ensure that the space you are working in is well ventilated. Avoid prolonged breathing of the vapor, and prolonged or repeated contact with the skin.

Type II dry-cleaning solvent is an approved nontoxic solvent for cleaning electrical and electronic equipments. The efficiency of this solvent, however, is somewhat less than inhibited methyl chloroform or trichloroethylene. Type II dry-cleaning solvent is also injurious to some types of insulation and insulating varnishes. Before using it to clean insulation or parts painted with insulating varnish, make a test by applying the solvent to a small spot on the surface to be cleaned to determine how it is affected by the solvent.

Do not use gasoline or benzine for cleaning IC equipments. Pure grain alcohol is recommended for cleaning some IC components, but must not be used on energized equipment or near any equipment where a spark is likely to occur.

Moisture

The battle against moisture never ends since it can creep into the smallest openings. Be sure that watertight covers are kept that way. When you remove a cover, check the condition of the gasket, the knife edge, and the securing bolts or dogs. Where possible, when checking an electrical circuit, use a connection box in a protected space. When moisture is discovered in an instrument or connection box, dry it out with a hot-air blower or an electric lamp. You can provide a reasonable degree of protection against the accumulation of moisture by energizing and running the equipment daily.

Salt and Fungus

When moisture is present, salt will corrode metals and conduct electricity. Fungus growths cause decay, rapid deterioration of insulating materials, and shorts or grounds in electrical circuits. Remove salt and fungus from your equipment immediately. In some cases, you can use fresh water to remove them. After cleaning the equipment, however, make sure the water evaporates completely. Methyl chloroform can also be used to clean away salt or fungus, but limit its contact time because it will attack electrical insulating materials. High concentrations of methyl chloroform vapors can be dangerous to life so make sure that the ventilation is adequate.

LUBRICATION

Lubricants are used to reduce friction between moving parts. Occasionally, lubricants are used for the purpose of preventing rust, oxidation, and corrosion. The applicable maintenance manual includes the lubrication instructions for the particular equipment. But no lubrication procedure will be effective unless it is performed regularly. Different components must be lubricated at different intervals; the recommended frequency of lubrication for each component must be followed.

Do not overlubricate your equipment. Excessive lubricant acts as an insulating blanket and prevents the dissipation of heat. Overfilling or overheating may cause overflow into adjacent electrical equipment. Lubricants generally deteriorate electrical insulation materials.

Cleanliness is important in lubrication. Dirt in a lubricant makes a damaging abrasive material. Plastic protective caps are provided for some types of grease fittings. Lubrication points must be cleaned prior to lubrication. If a cleaning solvent is used it must be wiped dry before the lubricant is applied.

Lubrication instructions are issued for almost all IC equipment. In addition, lubrication of the equipment is scheduled in the Planned Maintenance Subsystem (PMS). The PMS will indicate the type and amount of lubricants, lubrication points, and frequency of application. Other maintenance functions to be performed in conjunction with lubrication are also included in the PMS.

PAINTING AND VARNISHING

Repainting IC equipment should be done only when necessary to prevent corrosion due to lack of paint. General repainting in lieu of cleaning should not be done.

When IC equipment must be painted to combat corrosion, deenergize it first and paint only the area affected by the corrosion. Exercise caution in the use of scraping and chipping tools to avoid damage to the equipment. After the old paint has been removed, the equipment should be thoroughly cleaned with a vaccum cleaner.

Electrical insulating varnish should be applied to IC equipment only as necessary. Frequent applications of insulating varnish builds up a heavy coating which may interfere with heat dissipation and develop surface cracks. Do not apply insulating varnish to dirty or moist insulation, as the varnish will seal in the dirt and moisture and make future cleaning impossible.

Shellac and lacquer are forms of varnish but must not be used for insulating purposes. The two types of insulating varnishes commonly used in the Navy are clear baking varnish (grade CB), and clear air-drying varnish (grade CA). Grade CB is the preferred grade, however if it is not possible to bake the part to be insulated, grade CA is used.

Do not use grade CA or CB insulating varnish on insulating material other than class O or class A material. The classes of insulating materials used in shipboard electrical equipments are listed below:

- Class E insulation is an extended silicone rubber dielectric used in reduced diameter types of electric cables in sizes 3, 4 and 9.
- Class T insulation is a silicone rubber-treated glass tape used in reduced diameter cables in sizes 14 through 800.
- Class O insulation consists of cotton, silk, paper, and similar organic materials when neither impregnated nor immersed in a liquid dielectric. Class O insulation is seldom used by itself in electrical equipment.
- Class A insulation consists of (1) cotton, paper, and similar organic materials when they are impregnated or immersed in a liquid dielectric; (2) molded and laminated materials with cellulose filler, phenolic resins and other resins of similar properties; (3) films and sheets of cellulose acetate and other cellulose derivatives of similar properties; and (4) varnish (enamel) as applied to conductors.
- Class B insulation consists of mica, asbestos, fiber glass, and similar inorganic materials in built-up form with organic binding substances. A small portion of class A materials may be used for structural purposes.
- Class H insulation consists of (1) mica, asbestos, fiber glass and similar inorganic materials in built-up form with binding substances composed of silicone compounds or materials with equivalent properties; and (2) silicone compounds in the rubbery or resinous forms, or materials with equivalent properties. A small proportion of class A materials may be used where essential for structural purposes.
- Class C insulation consists entirely of mica glass, quartz, and similar inorganic material. Class C insulation, like class O, is seldom used alone in electrical equipment.

CLEANING ELECTRONIC EQUIPMENT

Most electronic equipment has a serious dust problem. This is a direct result of the heat problem. Heat is dissipated by air taken into the unit and circulated. Air filters are installed, but they are not 100 percent effective. The housing is not dustproof, so you can expect to find some dust in electronic units.

You should clean electronic units frequently. To clean an electronic assembly, use a soft brush and a vaccum cleaner with a nonmetallic hose. Keep in mind that even though the power is off, dangerous potentials may still be present.

Avoid using a portable blower or a compressed air hose to clean a cabinet or chassis. Dust may be blown into relay contacts or open switches. Oil inside the cabinet will usually be caused by a leaky oil-filled capacitor, which should be found and replaced.

Air filters must be cleaned periodically. If they are neglected, excessive heat may cause a breakdown of the equipment. Accumulated dust is removed by hosing the filter with soapy water. The filter is then dried, and reinstalled.

Ceramic insulators should be kept clean to prevent leakage and possible arc-overs. If wiping with a clean cloth is not enough, a cloth moistened with an approved solvent may be used. The insulator is then polished dry with another clean cloth.

Ferrule resistors and fuses should be removed from their clips, and corrosion or dirt removed from the components and clips. Use a cloth dipped in solvent, or if necessary, fine sandpaper to remove the dirt.

MANDATORY TURN-IN REPAIRABLES

Since you will no doubt encounter the terms "mandatory turn-ins" and "repairables" in the process of obtaining replacement parts from supply, you should understand the purpose of the repairables program and your responsibilities to it.

When any of your equipment fails, your primary concern is to locate the trouble, correct it, and get the equipment "back on the line." In most instances this involves tracing the trouble to a defective part, preparing a NAVSUP 1250 (or DD 1348), obtaining the replacement part from the supply storeroom and installing it, and throwing away the defective part.

The repairables program enters the picture when defective parts are expensive, and can be economically repaired at the factory. In these cases time and money are saved since it is quicker and cheaper to repair an item than to contract for and buy a new one—provided that the old item is promptly returned to supply in repairable condition.

For the repairables program to work as intended, you and others have certain responsibilities. At the time your request for a mandatory turn-in item is presented, supply must inform you that the defective item is to be returned. At this point, you start carrying out your responsibilities. You must:

- Remove the defective part without damaging it.
- Provide adequate protection to the part so that it will not be further damaged before it is turned in to supply. A good way to help prevent damage is to place the defective part in the same container in which you received the replacement part.
- Return the defective part to supply as soon as practicable.

DO NOT CANNIBALIZE THE PART FOR COMPONENTS WHICH YOU MIGHT POSSIBLY USE SOMETIME IN THE FUTURE.

When the required part is not in the storeroom, supply must then take appropriate action to obtain it. The failed part must still be returned and should be turned in before the replacement part is received. In this way, the failed part can enter the repair cycle and soon be available for reissue. This procedure should be followed except when the failed part will permit limited or reduced operation of equipment until the replacement is received.

PORTABLE ELECTRIC POWER TOOLS

Navy specifications for portable electric power tools require the electric power cord for the tool to be provided with a distinctively marked grounding conductor in addition to the conductors supplying power to the tool. Past practice was to use the red conductor for the grounding conductor in three-conductor cords, and the green conductor in four-conductor cords. Current specifications require that the green conductor be used for the grounding conductor in power cords for all portable electric equipment.

The end of the grounding conductor which is within the portable electric power tool is connected to the tool's metal housing. The other end of the grounding conductor must be grounded, (connected to the metal structure of the ship), when the tool is being used. Standard type plugs and receptacles automatically make this ground connection when the plug is inserted into the receptacle.

If a power tool is used in a nongrounding type receptacle, the metal housing of the tool must be grounded to the ship's metal structure by a separate grounding conductor. The grounding conductor must be at least as large in cross-sectional area as the power conductors. Care must taken to ensure a clean, tight electrical contact to the ship's metal structure. Securing the grounding conductor under a screw or bolt is preferred over the use of alligator or similar type clamps. Make the ground connection before inserting the plug into the receptacle, and remove the plug from the receptacle before removing the grounding conductor.

INSPECTING AND TESTING

Before using portable electric power tools for the first time, and periodically thereafter as directed, they should be inspected and tested as follows:

- Visually inspect the plug and power cord. Ensure that the conductors are tightly secured under the plug terminal screws, and that the plug contacts are clean. Pay particular attention to the ground contact. Clean the contacts with fine sandpaper if necessary.
- If the plug shell is made of brass, measure the insulation resistance between the brass shell and each plug contact with a megger. Move the cord with a push-pull, bending, and twisting motion while taking the reading. If the reading changes while the cord is being moved, or if the reading is below one megohm, the cord should be cut back and the plug rewired. Replace the brass shell with a nylon shell if available.
- Measure the resistance from the ground contact on the plug to the metal housing of the tool with an ohmmeter. Move the cord while taking the reading as before. A change in the resistance reading while moving the cord usually indicates broken strands in the grounding conductor, and requires rewiring the plug or replacing the power cord. The reading must be below one ohm to be satisfactory.
- Inspect the power cord for physical damage such as cuts, cracks, tears, chafing, and exposed bare conductors. Replace defective power cords rather than repairing them with tape.
- Visually inspect the power tool for any mechanical defects, or signs of dampness. Ensure that mechanical parts are not jammed.
- Measure the insulation resistance between each power line contact on the plug and the metal housing of the tool with a megger. Take readings with the tool switch in the ON and OFF positions. An insulation resistance reading of one megohm or above is satisfactory. If the reading is below one megohm the tool should not be used. Low insulation resistance readings may be caused by foreign matter such as dirt, carbon dust, and grease inside the electric motor for the tool. If this is the case, cleaning the motor will bring the readings up to a satisfactory value. Moisture inside the motor is also a frequent cause of low insulation resistance. If this is suspected, the moisture may be removed by drying the tool in an oven.

When replacing plugs and power cords for portable electric power tools, make all connections securely and in a workmanship like manner. There must be no loose strands of wire protruding from under terminal screws. Use standard crimp or solder type wiring terminals, or form the conductor ends into an eyelet or hook, and coat them with solder to bond the strands together.

VACUUM CLEANER

The vacuum cleaner is the best by far of the cleaning methods mentioned earlier. If treated properly it can save you much time and trouble. As with the other power tools this piece of equipment should be inspected carefully before use and all electrical safety precautions observed. The approved vacuum cleaner for use around electrical and electronic equipment should have at all times a nonconductive plastic or rubber nozzle to preclude any chance of shock to the operator. A suction is always preferable to blowing air into the piece of equipment that is being serviced and cleaned. Some of the small hand type vacuum cleaners are equipped with heater coils and may be used to dry out small motors and controllers that have a low resistance reading due to condensation or water spray. This is accomplished by a switch on the motor that reverses the blower.

COMMON HANDTOOLS (ELECTRIC)

The most common electric hand tools you will be using are the electric portable drill and the electric soldering iron. Both are covered in Tools and Their Uses, NAVPERS 10085-B, and you should familiarize yourself thoroughly with them.

MOTORS AND GENERATORS

Preventive maintenance of motors and generators consists mainly of cleaning, lubricating, and inspecting and servicing bearings, collector rings, and brushes.

CLEANING

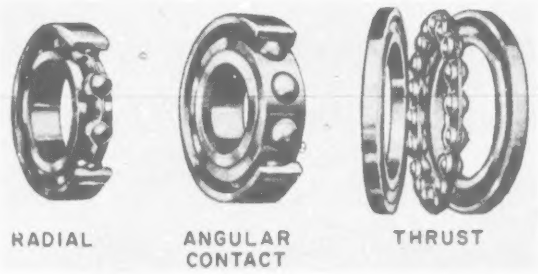
Motors and generators are cleaned by using wiping cloths, suction, compressed air, and solvents.

Wiping with a clean lint-free cloth (such as cheesecloth), is effective for removing loose dust or foreign particles from accessible parts of a machine. When wiping, do not neglect such parts as the end winding, mica cone extension at the commutator, collector ring insulation, and connecting leads.

The use of suction is preferred over the use of compressed air for removing abrasive dust and particles from inaccessible parts of a machine. If a vacuum cleaner is not available for this purpose, a flexible tube attached to the suction side of a portable blower will serve as a satisfactory substitute. Exhaust the blower to a suitable sump or overboard when used for this purpose.

Compressed air must be clean and dry when used for cleaning. Air pressure up to 30 pounds per square inch may be used on motors and generators up to 50 hp and 50 kw respectively. Pressures up to 75 pounds per square inch may be used on machines over 50 hp or kw.

The use of solvents for cleaning should be avoided whenever possible. Solvents must be used however, for removing grease and pasty substances consisting of oil and carbon or dirt. Exercise caution in using solvents to clean insulation as stated previously.



77.66
Figure 17-1. — Representative ball bearings.

BEARINGS

Basically all rolling bearings consist of two hardened steel rings, hardened steel rollers or balls, and separators. The annular, ring-shaped, ball bearing is the type of rolling bearing used most in motors and generators. This bearing is further divided into three types depending upon the load it is designed to bear as shown in figure 17-1.

The rotating element of a motor or generator may subject a ball bearing to any one or a combination of three loads — radial, thrust and angular. Radial loads are the result of forces applied to the bearing perpendicular to the shaft; thrust loads are the result of forces applied to the bearing parallel to the shaft; and angular loads are the result of a combination of radial and thrust loads.

Preventive maintenance for ball bearings requires periodic checks for bearing wear, and adequate lubrication.

Wear

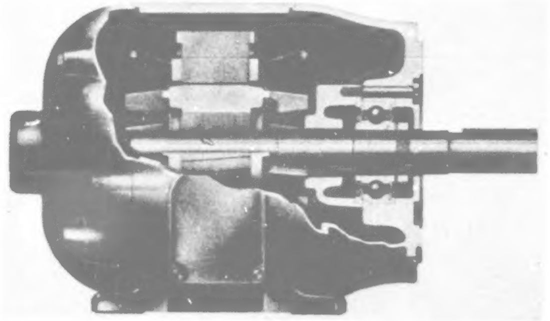
Measuring air gaps to determine bearing wear is not necessary on machines equipped with ball bearings. Ball bearing wear of sufficient magnitude as to be detected by air gap measurements would be more than enough to cause unsatisfactory operation of the machine.

The easiest way of determining the extent of wear in a ball bearing is to periodically feel the bearing housing while the machine is running to detect any signs of overheating or excessive vibration, and listen to the bearing for any unusual noise. These indications are comparative and caution must be exercised in analyzing them.

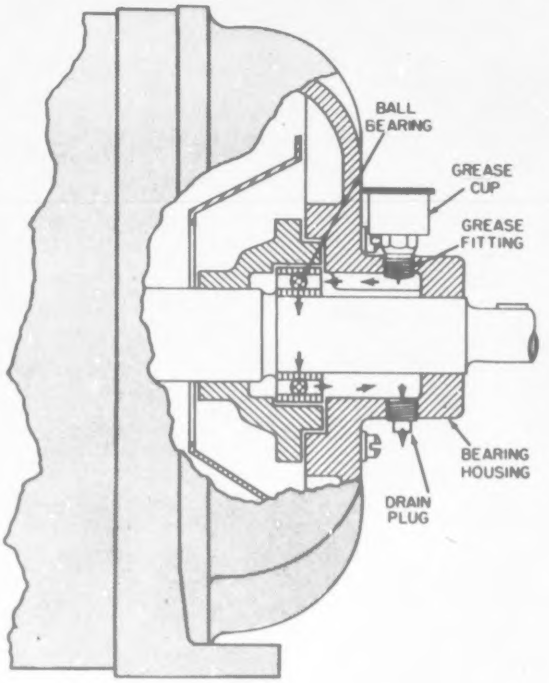
When checking for overheating, the normal running temperature of the bearing must be known before the check can be reliable. Rapid heating of a bearing is an indication of danger. A bearing temperature that is uncomfortable to the hand may not be a sign of danger if it has taken an hour or more to reach that temperature; whereas, serious trouble can be expected if that same temperature is reached within the first 10 or 15 minutes of operation.

The test for excessive vibration relies to a great extent upon the experience of the person making the test. He must be thoroughly familiar with the normal vibration of the machine to be able to correctly detect and interpret any unusual vibrations. Vibration is easily telegraphed, and a thorough search may be required to locate its source and to determine its cause.

A good method for testing for abnormal noise in a ball bearing is to place one end of a screwdriver or a steel rod against the bearing housing and the other end against the ear. If a loud, irregular grinding, clicking, or scraping noise is heard, trouble is indicated. The one sure method of checking ball bearings is also the most difficult. In this method, the bearing caps or other covers provided are removed and the actual condition of the bearing is observed. Each ball bearing should be inspected in this manner approximately every two years. The condition of the lubricant in the bearing may be checked at this time.



77.67
Figure 17-2. — Motor with permanently lubricated ball bearings.



77.68
Figure 17-3. — Grease-lubricated ball bearings.

Lubrication

Many motors and generators are equipped with permanently lubricated ball bearings, and require no additional lubrication throughout their life. A permanently lubricated ball bearing is shown in figure 17-2. Note the absence of grease fittings on the motor.

Ball bearings other than the permanently lubricated type require periodic lubrication with grease or oil. The parts of a grease-lubricated ball bearing are shown in figure 17-3.

Motors and generators provided with bearings that should be lubricated with grease are now normally delivered from the manufacturer with the grease cups removed from the bearing housing and replaced with pipe plugs. The grease cups are delivered with the onboard repair parts or special tools. It is recommended that grease cups be attached to motors and generators only when the bearings are being greased. When the grease cup is removed from the bearing housing after a bearing has been greased, the hole which remains should be plugged with a suitable pipe plug. When this procedure is used the grease cups should remain in the custody of responsible maintenance personnel and can be stored in the workshop area. CARE SHOULD BE TAKEN TO MAKE SURE THAT A GREASE CUP IS CLEAN BEFORE IT IS USED TO ADD GREASE TO A BEARING AND THAT THE PIPE PLUG USED TO REPLACE THE GREASE CUP AFTER GREASING IS ALSO CLEAN.

The frequency with which grease must be added depends upon the service of the machine and the tightness of the housing seals.

Ordinarily, the addition of grease will not be necessary more often than once in six months. The use of excessive quantities of grease is to be avoided because it has been a major cause of bearing failures. When a bearing housing is too full of lubricant, the churning of the grease generates heat which in turn causes deterioration of the grease. Under these conditions the grease separates into oil and minute abrasive particles, becomes increasingly sticky, and tends to seal the bearing against fresh lubricant. When grease is added, it should be done as follows:

1. Wipe outside of grease fitting and drain plug free of all dirt.

2. Remove bearing drain plug and make sure the passage is open by probing with a clean screwdriver or similar tool.

3. Remove pipe plug on top of grease pipe. Select proper grease cup and install bottom portion of cut on the grease pipe. In the top portion of the grease cup put only enough grease to half fill it.

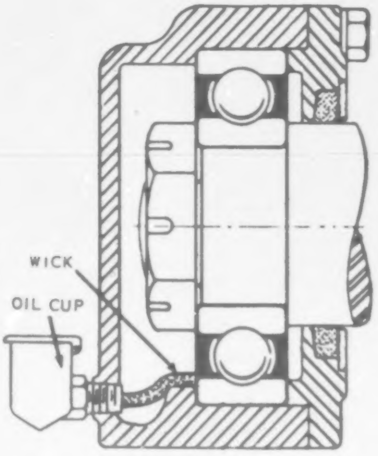
3. Clean out the receptacle of the grease fitting down to the neck, then fill with clean grease.

5. Replace the grease cup and SCREW IT DOWN AS FAR AS IT WILL GO.

6. Run the machine and let grease run out of drain hole until drainage stops (normally about 30 minutes). Remove grease cup and replace pipe plug.

7. Replace the drain plug.

8. DO NOT USE A GREASE GUN TO LUBRICATE BEARINGS UNLESS THERE ARE NO OTHER MEANS AVAILABLE. If a grease gun must be used, remove the drain plug in the bearing housing while greasing and use extreme care to avoid inserting too much grease or applying more than just enough pressure to get the grease into the housing. Grease gun fittings must be removed from the machine after use and replaced with a pipe plug.



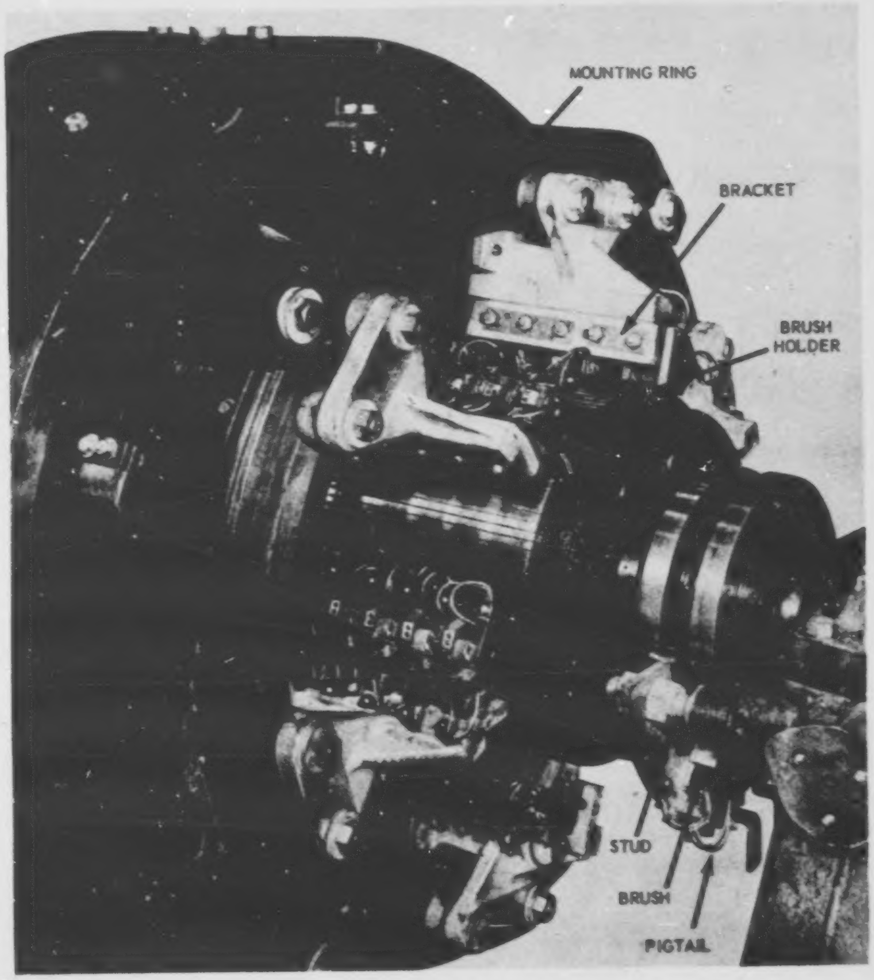
77.69
Figure 17-4.—Wick-fed ball bearings.

Some motors and generators are equipped with oil-lubricated ball bearings. Lubrication charts or special instructions are usually furnished for this type of bearing and should be carefully followed. In the absence of instructions, the oil level inside the bearing housing should be maintained approximately level with the lowest point of the bearing inner ring.

A common method by which the oil level is maintained in ball bearings is the wick-fed method. In this method the oil is fed from an oil cut to the inside of the bearing housing through an absorbent wick. The wick also filters the oil and prevents leakage through the cup in the event a pressure is built up within the housing. A wick-fed oil-lubricated ball bearing is shown in figure 17-4.

BRUSHES

The brushes used in motors and generators are usually made of carbon and bear against a commutator or collector ring to provide a sliding contact for passage of current to an external circuit. An adjustable spring is usually provided to maintain proper pressure of the brush on the commutator or collector ring. Constant-pressure brush holders are used in some small machines. A d.c. generator brush holder and



77.70

Figure 17-5.—Brush-holder and rigging assembly.

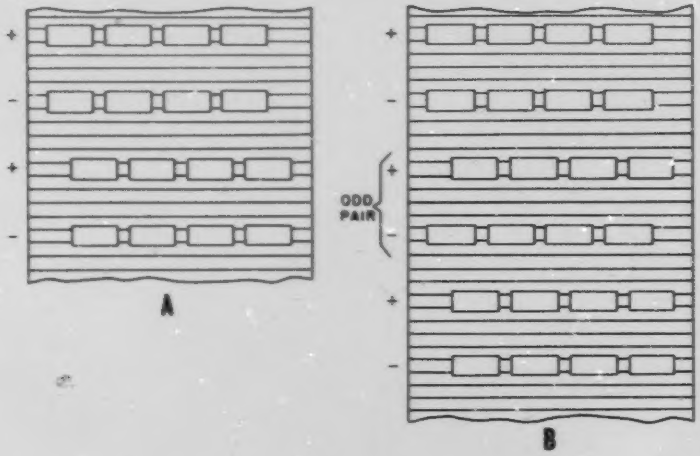
brush-rigging assembly are shown in figure 17-5.

Brushes are manufactured in different grades to meet the varied types of service. Only the grade of brush recommended by the manufacturer should be used in a machine.

Care

If the correct grade of brush is used, and the brushes are correctly adjusted and cared for, good commutation will result. The brushes and brush rigging should be inspected periodically to ascertain their condition. The brush pigtails must be securely connected at the brushes and terminals. Brushes should move freely in their holders, but must not be loose enough to vibrate. They should be replaced when they are worn down to half their original length, or if chipping has occurred at the corners or edges. The brush holders and brush rigging should be cleaned before inserting the new brushes.

The pitting effect on the commutator differs under the positive and negative brushes, making it necessary to stagger the brushes to prevent grooving of the commutator, as shown in figure 17-6. The positive and negative brushes



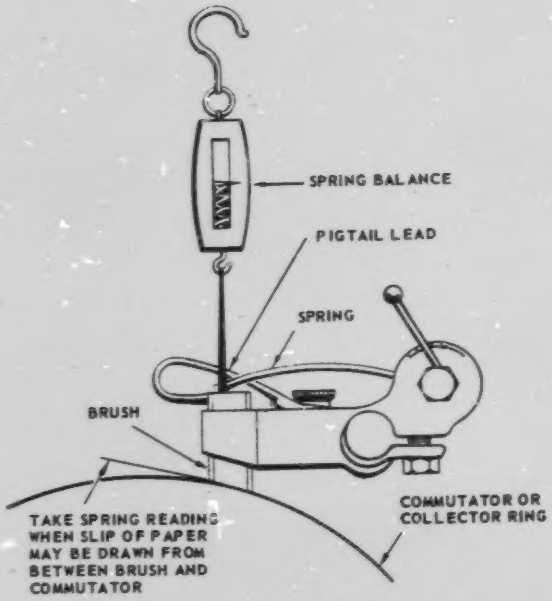
77.71

Figure 17-6. — Method of staggering brushes.

are staggered in pairs so that the differences in pitting effect are distributed equally over the full brush-contact area of the commutator surface (fig. 17-6A). In a machine having an odd number of pairs, it is impossible to stagger all the brushes in this manner. In this machine, the brushes are staggered as before, except that the brushes of the odd pairs are staggered separately (fig. 17-6B).

Except for the constant pressure types, as the brushes wear, the brush spring tension must be changed to keep the brush pressure approximately constant. Brush pressure should be as specified in the manufacturer's technical manual for the machine concerned. Pressures as low as 1 1/2 pounds per square inch of contact area may be specified for large machines, and as high as 8 pounds per square inch for small machines. Where manufacturer's technical manuals are not available, a pressure of 2 to 2 1/2 pounds per square inch of contact area is recommended for integral horsepower and kilowatt machines, and about twice that pressure for fractional horsepower and kilowatt machines.

To measure brush pressure, attach a small spring balance to the pigtail end of the brush, insert one end of a strip of paper between the brush and the commutator, then exert a pull on the spring balance in the direction of the brush holder axis (fig. 17-7). Note the reading of the spring balance when the pull


SPRING BALANCE
PIGTAIL LEAD
SPRING
BRUSH
TAKE SPRING READING WHEN SLIP OF PAPER MAY BE DRAWN FROM BETWEEN BRUSH AND COMMUTATOR
COMMUTATOR OR COLLECTOR RING

77.72

Figure 17-7. — Measuring brush pressure.

is barely sufficient to release the paper so that it can be pulled from between the brush and the commutator without resistance. Divide this reading by the contact area of the brush to obtain the brush pressure.

Seating

Accurate seating of the brushes must be assured where their surfaces contact the commutator. Sandpaper and a brush seater are the best tools for seating.

Disconnect all power from the machine, and exercise caution to ensure that the machine will not be inadvertently started, before using sandpaper to seat the brushes. The brushes to be seated are lifted and a strip of fine sandpaper approximately the width of the commutator is inserted (sand side up) between the brushes and the commutator. With the sandpaper held tightly against the commutator surface to conform with the curvature, and the brushes held down by normal spring tension, pull the sandpaper in the direction of normal rotation of the machine (fig. 17-8). When returning the sandpaper for another pull, the brushes must be lifted. This operation is repeated until the brushes are accurately seated. Use a finer grade of sandpaper when finishing. Use a vacuum cleaner to remove dust while sanding. After the brushes are seated, thoroughly clean the commutator and windings to remove all carbon dust.

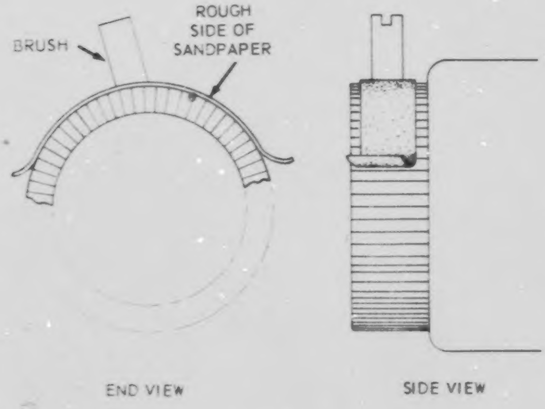


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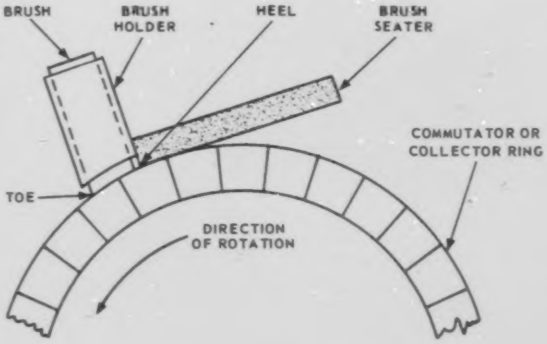
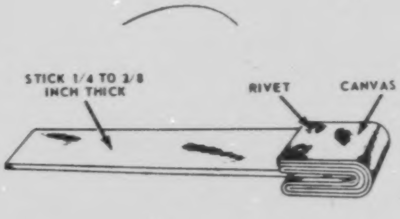
Figure 17-8.—Method of sanding brushes.



1.53

Figure 17-9.—Using the brush seater.

The brush seater is made of a compound of a mild abrasive material loosely bonded, and is formed into a stick about 5 inches in length. To use the brush seater, touch it lightly for a second or two at the heel of the brush while the machine is running (fig. 17-9). Pressure may be applied to the brush by setting the brush spring tension at maximum or by pressing a stick of insulating material against the brush. After using the brush seater, clean the machine in the same manner as for sanding brushes.



1.54.1

Figure 17-10A.—Canvas wiper.

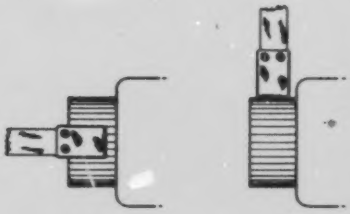
COMMUTATORS AND COLLECTOR RINGS

After being used approximately two weeks, the commutator of a machine should develop a uniform, glazed, dark brown color on the places where the brushes ride. If a nonuniform or bluish colored surface appears, improper commutation conditions are indicated. Periodic inspections and proper cleaning practices will keep commutator and collector-ring troubles at a minimum.

Cleaning

One of the most effective ways of cleaning the commutator or collector rings is to apply a canvas wiper while the machine is running. The wiper can be made by wrapping several layers of closely woven canvas over the end of a strong stick between one-fourth and three-eighths inch thick (fig. 17-10A). The canvas may be secured with rivets if they, in turn, are covered with linen tape to prevent the possibility of their contacting the commutator. When the outer layer of canvas becomes worn or dirty, it is removed to expose a clean layer. The wiper is most effective when used frequently. On ship's service generators, it may be desirable to use the wiper once each watch. When using the wiper, exercise care to keep from fouling moving parts of the machine. The manner of applying the wiper to a commutator is illustrated in figure 17-10B.

When machines are secured, a toothbrush can be used to clean out the commutator slots, and clean canvas or lintless cloth may be used for wiping the commutator and adjacent parts. In addition to being cleaned by wiping, the commutator should be periodically cleaned with a vacuum cleaner or blown out with clean, dry air.



1.54.2

Figure 17-10B.—Using canvas wiper on commutator.

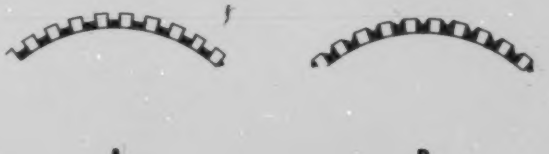
Do not sandpaper a commutator if it is operating well, even if long service has developed threading, grooving, pits, burn areas between bars, longitudinal irregularities, etc., unless sparking is occurring or brushes are wearing excessively. If a decision is made that the commutator should be sanded, use a fine grade of sandpaper (No. 0000 preferred, but in no case coarser than No. 00). Sandpapering may also be used to make emergency reduction of high mica, or to polish finish a commutator which has been stoned or turned. The sandpaper, attached to a wooden block shaped to fit the curvature of the commutator, is moved slowly back and forth across the surface of the commutator while the machine is running at moderate speed. Rapid movement or the use of coarse sandpaper will cause scratches. Emery cloth, emery paper, or emery stone should never be used on a commutator or collector ring since there is too much danger of causing electrical shorts.

Commutator Undercutting

Poor commutation will develop if the commutator bars are worn down to, or below, the level of the mica. The mica should be undercut to a depth of between one sixty-fourths inch and three sixty-fourths inch below the level of the commutator bars. A small motor-driven, circular saw especially designed for this purpose, a slotting file having an angle of 60° between faces, or a hacksaw blade that has been ground to the right thickness and fitted to a handle may be used for undercutting mica. Figure 17-11 shows properly and improperly undercut commutators.

Truing up the Commutator

A commutator should be trued in place only if its condition has become so bad it cannot wait



73.229

Figure 17-11.—A. Commutator properly undercut; B. Commutator improperly undercut.

until the next shop overhaul for reconditioning. Large commutators in the 125-850 rpm range, as fitted on most electric propulsion motors and generators, usually operate satisfactorily with runouts up to 3 mils (.003"). Under any conditions, do not attempt to true a commutator in place unless there is sparking, excessive brush wear, or brush movement sufficient to fray the brush pigtails and wear the hammer plates. Do not confuse brush chatter with brush movement by runout. Sandpaper will not correct flat spots, grooves, eccentricity, or out of round. Measures which will correct some or all of these conditions are:

1. Hand stoning.
2. Grinding with a rigidly supported stationary or revolving stone.
3. Turning.

There are a number of grades of cummutator stone from very coarse to very fine that can be used for hand stoning or grinding with a rigidly supported stone. Use the finest stone that will do the job in a reasonable time. Do not use coarse stones as they tend to produce scratches which are hard to remove.

Regardless of the method it is essential that the cut be strictly parallel with the axis of the machine. Otherwise, a taper on the commutator will result.

Do not disturb the commutator clamping bolts unless there is direct evidence that the bars are loose (one or more high bars). Then use a calibrated torque wrench and tighten only to the values as specified by the manufacturer. For propulsion motors and generators, these values are available in the Naval Ship Systems Command. Make all other needed repairs such as balancing, rebrazing armature connections and repairing insulation faults prior to truing the commutator.

When practical, the armature should be removed from the machine and placed in a lathe for grinding. If this is impractical, the commutator can be ground in the machine provided:

1. The windings can be adequately protected from grit and suitable supports can be found for the stone, and
2. There is not too much vibration.

When grinding the commutator in the machine, the armature can be rotated by an external prime mover or, in the case of motor, by supplying power through just enough brushes to take care of the load. It is preferable to discard these brushes after grinding. Old brushes may be used for this purpose. Whenever grinding is done in a motor, take care to avoid electric shock and fouling of any of the equipment used with the moving parts of the motor.

COMMUTATOR SURFACING STONES. Commutator surfacing stones with tool post handles are carried in stock in various sizes and grades (fine, medium, coarse, etc.) in the Ships Parts Segment of the Navy Supply System. When used, the stone should be rigidly clamped in a holder and substantially supported to keep the stone from chattering or digging into the commutator. The supports must provide for axial motion of the stone. Heavy cuts must be avoided since the stone wears away as it is moved back and forth. If a heavy cut were taken, the commutator would not have the same diameter at both ends.

ROTATING GRINDER. A medium soft grinding wheel should be used so that the face will not fill up with copper too rapidly. Use a light cut even if the commutator is badly distorted and a large number of light cuts are needed. If a heavy cut is used, the commutator may be ground to a noncylindrical shape and initial eccentricity may be retained because of the elasticity of the support. The speed of the wheel should be that recommended by the manufacturer. The speed of the commutator should be moderate (one-half to three-fourths normal speed) until most of the eccentricity has been removed. After this the commutator should be rotated at approximately normal speed.

After the truing up has been completed whether by stoning, grinding, or turning, finish with a fine grade of stone or sandpaper, undercut the mica, chamfer the commutator bars, clean the commutator and brush holders, and wipe off the brushes with a clean, dry, lintless cloth.

Hand Stoning

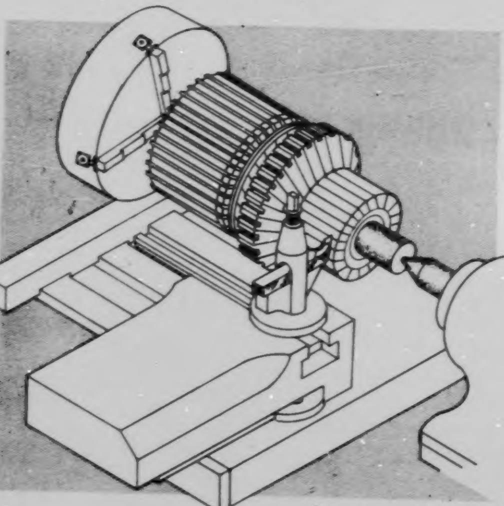
Hand stoning will remove flat spots, grooves, scoring and deep scratches but will not correct eccentricity, high bars, or an out-of-round condition. The machine should be running at, or only slightly below, rated speed. Generators can be turned by their prime movers. For motors, remove all but enough brushes to keep the armature turning at the proper speed. It is preferable to use old brushes for this purpose and discard them after the stoning is completed.

The stone should be formed or worn to the curvature of the commutator and should have a surface substantially larger than the largest flat spot to be removed. The stone is held in the hand and moved very slowly back and forth parallel to the axis of the commutator. Do not press too hard to the stone, just enough to keep it cutting. Undue haste or crowding of the stone will result in a rough surface and sometimes a noncylindrical shape of the commutator. Exercise care to avoid electric shock, or jamming the stone between fixed and moving parts of the machine.

Stoning by Machine

Stoning should be by machine in case of eccentricity, high bars, or out-of-round conditions. The following three methods of stoning by machine are employed:

1. In the case of some of the larger open and dripproof machines, a commutator dressing stone tool is mounted on the frame of the machine and holds a commutator stone against the commutator as the armature is rotated.
2. The armature may be removed from the machine and mounted in a lathe where it is rotated. The commutator stone is mounted in the tool post and fed to the commutator.
3. The armature may be removed from the machine and mounted in a lathe where it is rotated. A rotating precision grinder is mounted in the tool post and the grinder wheel fed to the commutator.



77.74
Figure 17-12.—Truing commutator by turning.

Turning the Commutator

When armatures are removed to the shop for overhaul, the armature should be placed in a lathe for truing the commutator. (fig. 17-12). Before truing, make sure the shaft is straight and is in otherwise good condition. Cut only enough material to true. Small pits, burn spots between bars, or other mechanical imperfections in the bars do not have to be removed unless they would interfere with the free sliding of the brushes.

The armature should be supported in a lathe and a diamond point tool should be used. This should be rounded sufficiently so that the cuts will overlap and not leave a rough thread on the commutator. The proper cutting speed is about 100 feet per minute and the feed should be about 0.010 inch per revolution. The depth of cut should be not more than 0.010 inch. The reasons for a light cut are the same as for grinding. In addition, when taking a heavy cut, a turning tool tends to twist the commutator bars and cut deeper at one end than at the other.

After turning the commutator, it should be finished with a hand stone and sandpaper.

If balancing equipment is available the entire rotating assembly should be balanced before it is reinstalled in the machine.

Restoring the Commutator Film

After the oxide film has been removed from the commutator surface by sandpapering, stoning, grinding, or turning, it is necessary to restore the film before the machine is operated at or near full load.

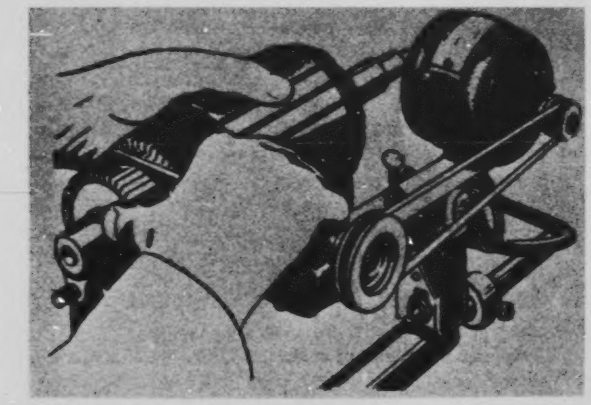
Prior to passing any current through the commutator, the surface should be mechanically smooth and any sharp edges or slivers on the bar edges should be removed by a hand-leveling tool. If there are noticeable scratches or roughness, the commutator should be burnished by very fine sandpaper (no coarser than No. 0000) or by a commercial burnishing stone, such as covered by Military Specification MIL-S-17346. After burnishing, carefully brush any debris from between the commutator bars. Any commutator which is shop overhauled should have the commutator surface smoothed, bar edges leveled, and be cleaned between the bars prior to being reassembled in the motor or generator.

Any commutator which has been resurfaced should undergo a reasoning process to restore its oxide film prior to being operated at or near full load. Start with 25 percent load and operate for 4 hours. Then increase load by 10 percent increments every hour until full load is reached. If it is urgent to get the machine on full load in the minimum time, run at 25 percent load for 3 hours and then increase load by 15 percent every hour until full load is reached. This shorter seasoning period is not recommended unless the machine is urgently needed.

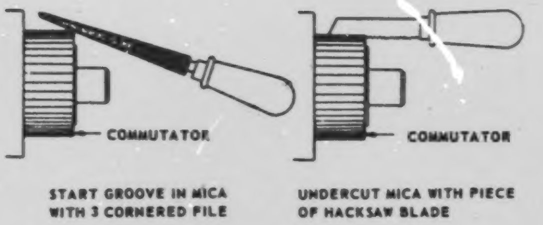
Undercutting Mica

High mica or feather-edge mica may cause sparking, a rough or uneven commutator surface, streaking or threading, or numerous other difficulties. Rough or uneven commutator surfaces may also be caused by failure to chamfer the commutator segments after undercutting. Many tools are now available for undercutting, chamfering, and smoothing slot edges.

A rotary, motor driven undercutter (fig. 17-13A) may be used to undercut mica. The rotary cutters are either U or V-shaped. U slots will give long wear and are best suited to slow speed machines or machines which operate in a clean atmosphere and require little maintenance. V slots, which are more quiet than U slots, are better where dirt and dust are present. The proper thickness for a U-shaped cutter is equal to the thickness of the mica plus or minus 0.001 inch. In general, it is best not to cut U-shaped slots deeper than 1/32 or at most 3/64 inch. V-shaped slots are cut to a depth which will remove some copper at the top.



2.87
Figure 17-13A.—Undercutting commutator mica with undercutter.


COMMUTATOR
COMMUTATOR
START GROOVE IN MICA WITH 3 CORNERED FILE
UNDERCUT MICA WITH PIECE OF HACKSAW BLADE

2.88
Figure 17-13B.—Undercutting mica with a hacksaw blade.

If a mica undercutter is not available, you can use handtools and cut the mica as shown in figure 17-13B.

Use care in undercutting mica so as not to widen commutator slots by removing metal from bars. Do not leave a thin edge of mica next to bars.

Do not use lubricant, and do not cut too deeply. After removing the high mica, smooth off all burrs., polish the commutator and test.

MAINTENANCE TECHNIQUES

SOLDERING

The correct procedure for soldering is given in Basic Electricity, NavPers 10086-B; therefore, it will not be covered here. Let us consider for a moment the end product—properly and improperly made soldered joints.

A good well-bonded connection is clean, shiny, smooth, and round. It shows the approximate outline of the wire and terminals. The wire and terminals are completely covered, and the solder adheres firmly. The insulation is close but not in the hole or slot; it is approximately 1/8 inch from the terminal. It is not charred, burned, nicked, or covered with rosin. A film of rosin may remain on the joint and need not be removed unless the joint is in a high frequency circuit or unless fungus-proofing is anticipated.

Soldered joints may be defective for a variety of reasons, such as the following.

A COLD solder joint has a dull appearance and a crystallized texture. Because of the poor union between the wire and terminal, the joint will in time develop high resistance as the metals oxidize. This type of joint is caused by insufficient heat during soldering, and may be repaired by reheating.

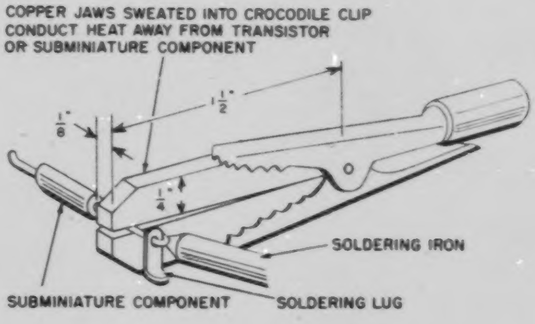
A ROSIN joint is so named because the wire is held by rosin rather than solder. The flux is spread over the terminal, and instead of the solder bonding with the terminal, the solder settles on top of the rosin. The joint may have all the appearances of a good joint, but a little pressure will cause movement or an ohmmeter will indicate an open. A rosin joint occurs when using a "cold" iron or one that is too small. In most cases, merely applying a hot iron will clear up a rosin joint.

A DISTURBED solder joint has an irregular or crystallized appearance and the solder may be chipped off with a fingernail or a pointed tool. It is caused by the wire being moved before the solder has fully set. It may be repaired in the same manner as the cold solder joint.

An INSUFFICIENT solder joint can introduce high resistance in the circuit and, as current flows, undesirable heat. It may loosen and cause an open or intermittent operation depending upon the amount of oxide present. This heat or a visual inspection may reveal this condition, but it may be necessary to use an ohmmeter to detect this type of solder joint. To repair it, it should be taken apart; and after cleaning off the oxide, the joint should be resoldered correctly.

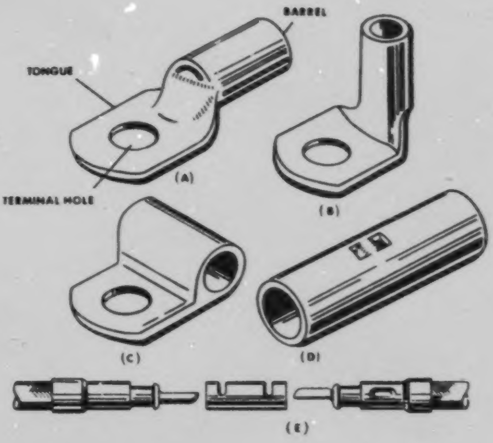
A NO-SOLDER joint may cause noise due to oxide or vibration; the circuit may open entirely. A visual inspection and an ohmmeter will indicate this condition. The joint should be taken apart, cleaned, and then resoldered correctly. There are many other soldering defects, such as excessive solder, loose solder, and insulation too close or too far from the joint.

Occasionally some special techniques are required in soldering. Such an occasion occurs in electronic equipment using miniaturized components. In such equipment, the physical dimensions of resistors have greatly decreased and application of a soldering iron close to the body of these small carbon composition resistors causes a PERMANENT change in resistance. Overheating of these resistors and other components during soldering can be avoided only by restricting heat conduction along the terminating leads.


COPPER JAWS SWEATED INTO CROCODILE CLIP CONDUCT HEAT AWAY FROM TRANSISTOR OR SUBMINIATURE COMPONENT
1/8"
1 1/2"
1/4"
SOLDERING IRON
SUBMINIATURE COMPONENT
SOLDERING LUG

12.243
Figure 17-14.—Details of thermal clamp type shunt.

The most acceptable means of preventing this overheating is by use of a thermal shunt, (fig. 17-14). This shunt should be placed as close to the resistor and as far from the joint as possible. Be certain that the clamp does not contact both the resistor and the joint. If



12.244
Figure 17-15.—Basic types of solderless terminals.

you don't have a clamp type shunt, and don't have time to make one, you can use small needlenose pliers. If you wrap a rubber band tightly around the handles, the pliers will grip the resistor lead so that you won't have to hold them in place while you solder.

CRIMPING

The crimp-on or solderless terminals require relatively little operator skill. Another advantage is that the only tool necessary is the crimping tool. The connections are made more rapidly; they are cleaner and more uniform. Due to the pressure exerted and the materials used, the crimped connection or splice, properly made, has an electrical resistance that is less than that of an equivalent length of wire.

The basic types of terminals are shown in figure 17-15. A shows the straight type, B the right angle type, C the flag type, D the splice type, and E the disconnect splice type. There are also variations of these types, such as the use of a slot instead of a terminal hole, three- and four-way splice type connectors, etc.

Various size terminal or stud holes will be found for each of the different wire sizes. A further refinement of the solderless terminals is the insulated terminal; the barrel of the terminal (fig. 17-15) is enclosed in an insulating material. The insulation is compressed along with the terminal barrel when crimping, but is not damaged in the process.

This eliminates the necessity of taping or tying an insulating sleeve over the joint.

There are two types of crimping tools used with copper terminals. For wire sizes AWG (American Wire Gage) 10 or smaller, a small pliers type of crimper is used. For the larger wire sizes, a large and powerful pincer type crimper is used. The small pliers type crimper has several sizes of notches for the different size terminals. The large pincer type is adjusted to an index mark for the different size terminals. Care should be exercised to select the correct crimping tool for the particular terminal. Do not tin stranded wires. (The solder forms a line of stress concentration on each strand, which may result in vibration failure.) Always use insulation-grip terminals for wire sizes No. 10 AWG and smaller, regardless of application, to protect conductors from mechanical vibration and fatigue.

The procedure for crimping a copper terminal to a copper wire is as follows:

1. Strip the cable insulation carefully to avoid cut or nicked strands. Remove the proper length of insulation.

2. See that the stripped cable end extends into the terminal barrel for the full length of the barrel.

3. Center the terminal barrel in the crimping tool so that pressure on the strands, from the crimped strands to the unsecured strands, will be gradual, thus preventing stress concentrations.

4. Now crimp the terminal, making sure that the crimper is fully closed to ensure proper crimping.

5. Inspect the joint with a probe through the inspection hole. The end of the conductor must come to the edge of the inspection hole.

If the correct tools are used, and the proper procedures followed, the connections will be more effective electrically, as well as mechanically, than soldered connections. A visual inspection is very important for it will reveal oxidation, deterioration, overheating, and broken conductors. In some cases it may be necessary to check these connections with an ohmmeter; the proper resistance, for all practical purposes should be zero. Any defective terminal should be removed and a new terminal crimped on.

TRANSISTORIZED AND PRINTED CIRCUITS

The use of transistors and other semiconductors in IC equipment is constantly increasing. Because of its versatility, the transistor is used in many circuit applications. Its miniature dimensions make the transistor particularly suitable for use in unitized and modular constructed equipment. For the same reason (miniaturization and compactness), troubleshooting equipment containing transistors is made more difficult.

The maintenance and repair of equipment using transistors has raised many questions concerning proper servicing procedures and troubleshooting practices that have been used previously in electron-tube circuitry.

Like electron tubes, transistors come in various shapes and sizes and often are classified according to their use and application. The characteristics of transistors are presented in specification sheets, or they may be included in transistor manuals.

It should be noted that the primary difference between the operation of a transistor and an electron tube is that the electron tube is voltage operated, and the transistor is current operated.

Comparison of a given transistor and an electron tube shows that there is a great similarity in their functions. Therefore any knowledge you have gained on electron tube equipment will be useful in the servicing of transistorized circuits. There are many differences however, between a transistor and an electron tube from the standpoint of servicing. For instance, the reliance placed on the senses of sight, touch, and smell in the inspection of electron tube circuits is not feasible in transistor circuits. Many transistors develop so little heat that nothing can be learned by feeling them. High frequency transistors hardly get warm. Usually if a transistor (except a high-power transistor) is hot enough to be noticeable, it has been damaged beyond use.

In electron tube circuits, a quick test is often made by the tube substitution method; that is by replacing the tube suspected of being bad with one known to be good. In transistorized circuits, the transistors are frequently soldered in and the substitution method is impractical. Furthermore, indiscriminate substitution of transistors and other semiconductors should be avoided. It is preferable to test transistors using a transistor test set as discussed later.

TROUBLESHOOTING TRANSISTOR CIRCUITS

The first step in troubleshooting transistor circuits, as in the troubleshooting of electron tube circuits, is a visual inspection of the entire equipment. Loose connections, broken leads, and any other visible damage should be repaired before undertaking the next step of the troubleshooting procedure. A careful visual inspection will frequently shorten what could otherwise be a lengthy troubleshooting job.

When the visible defects have been corrected, and if the equipment is still inoperative, the next step is to determine the defective stage by means of a signal-substitution or signal-tracing method, and then analyze that stage for the defective component. Use a signal generator to locate the defective stage, then use a voltmeter and ohmmeter to determine the defective part or parts.

Most good quality test equipment used for electron tube circuit troubleshooting may also be used for transistor circuit troubleshooting. Signal generators, both RF and AF, may be used if the power supply in these equipments is isolated from the power line by a transformer. Before any tests are made with a signal generator, a common ground wire should be connected from the chassis of the equipment to be tested to the chassis of the signal generator before any other connections are made.

Signal tracers may be used on transistor circuits if the precautions concerning the power supplies are observed. Many signal tracers use transformerless power supplies; therefore to prevent damage to the transistor, an isolation transformer must be used.

Multimeters used for voltage measurements in transistor circuits should have a high ohms-per-volt sensitivity to ensure an accurate reading. A 20,000 ohms-per-volt meter or an electronic voltmeter (VTVM) with an input resistance of 11 megohms or higher on all voltage ranges is preferred.

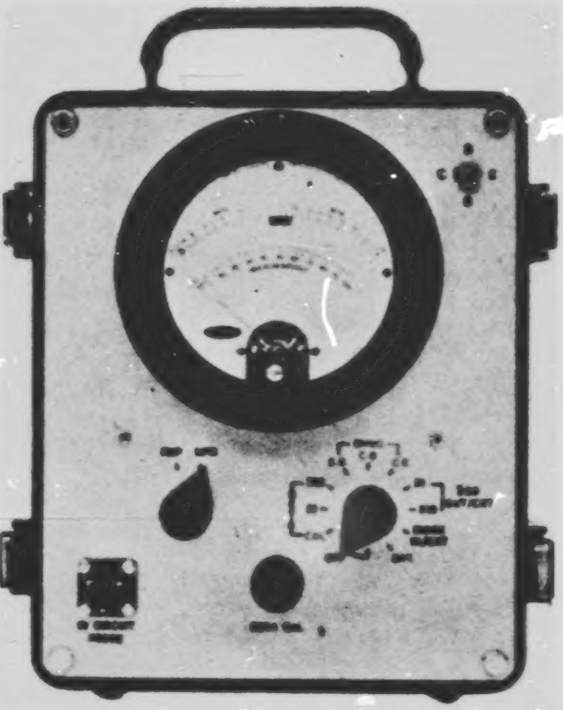
Ohmmeter circuits which pass a current of more than one milliampere through the circuit under test cannot be used safely in testing transistor circuits. Before using an ohmmeter on a transistor circuit, check the current it passes on all ranges. To check the current passed by the ohmmeter, set the meter up for resistance measurements and connect a milliammeter in series with the test leads. Observe the milliammeter reading on all ranges. Do not use any range for testing that passes more than one milliampere.

Conventional test prods, when used in the closely confined areas of transistor circuits, often are the cause of accidental shorts between adjacent terminals. In electron tube circuits the momentary short caused by test prods rarely results in damage, but in transistor circuits this short can ruin a transistor. Also, as transistors are very sensitive to improper bias voltages, the practice of troubleshooting by shorting various points to ground and listening for a click must be avoided. The sensitivity of a transistor to surge currents should always be borne in mind when testing transistor circuits.

Another change from conventional troubleshooting procedure that is required by transistor circuits is the use of a small, low-wattage soldering iron with a narrow point or wedge. Wattage ratings on the order of 35 to 40 watts are satisfactory. The common type of soldering gun or iron used on electron tube circuits should not be used on transistor circuits.

TESTING TRANSISTORS

Transistor test set AN/USM-206 (fig. 17-16) is a portable instrument engineered for the troubleshooting and repair of semiconductor circuits. It has been designed to preclude the possibility of externally induced or "self-made" failures by limiting the power that can be applied to the circuits under test. Accordingly, damage cannot occur to the semiconductor under test from the application of incorrect polarity. The test set measures the Beta of a transistor, the resistance appearing at the electrodes of a transistor or diode, the reverse leakage of a transistor or diode, a shorted or open condition of a diode, and the condition of its batteries. The transistor characteristics data book, NAVSHIPS 0969-002-7020, should be used for comparing the measured characteristic with the characteristic value of a good transistor.



26.237.1

Figure 17-16.—AN/USM-206 test set.

The test set operating instructions and equivalent circuits are shown in figure 17-17.

Testing With Ohmmeter

While the AN/USM-206 tester or its equivalent is required to test all parameters of the transistor, the ohmmeter function of either the VOM or VTVM can be used with fairly accurate results in determining whether a transistor is open or shorted. Before using an ohmmeter to test a transistor, check the current that the ohmmeter passes on all ranges as described previously. Do not use any range for testing which passes more than one ma.

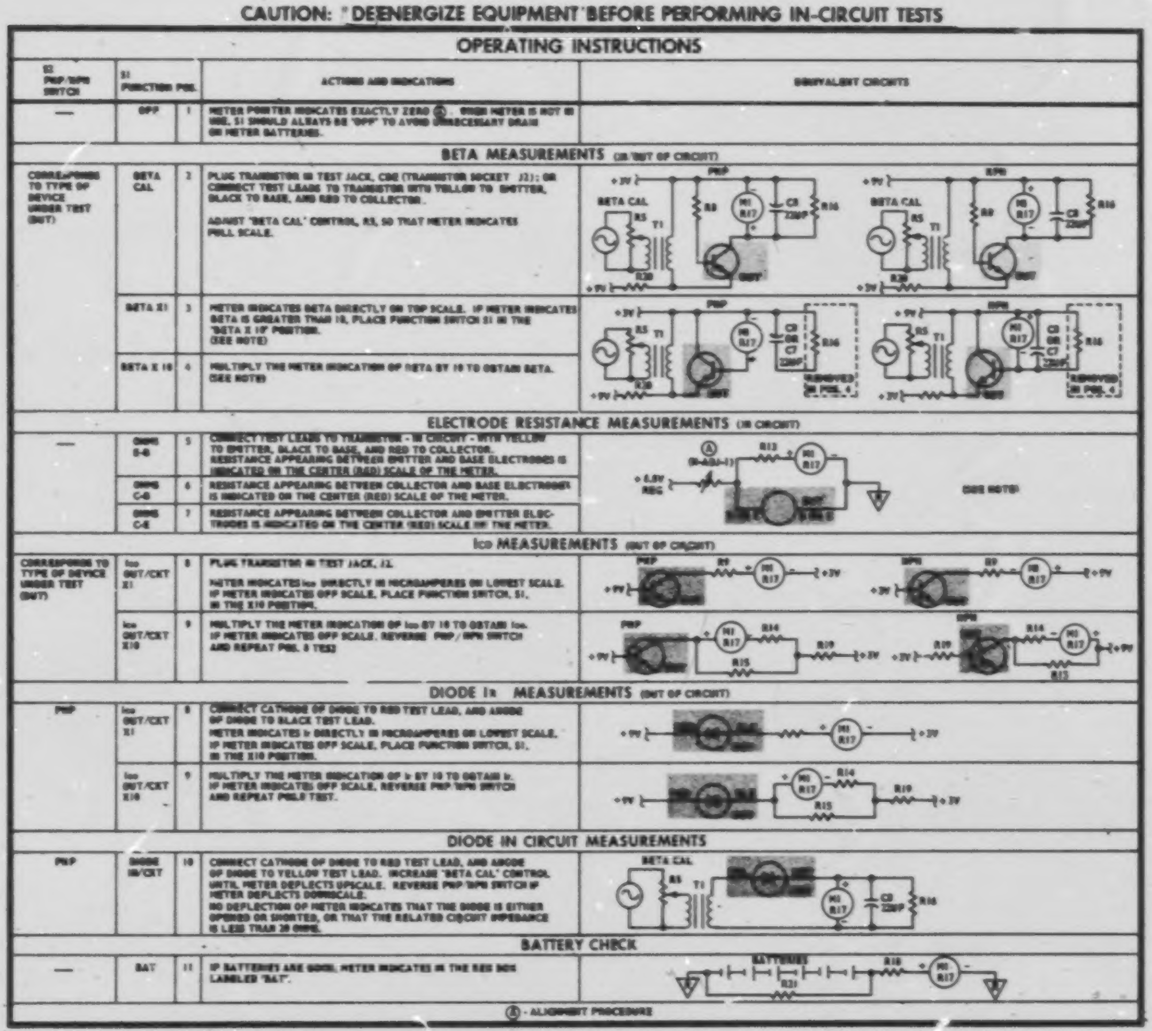
The most common method of testing a transistor with an ohmmeter is to take resistance readings across each junction (emitter-base and base-collector) in both directions. If the transistor is good, the readings in the forward direction will be somewhere around midscale on the meter, and the readings in the reverse direction will be near the infinity mark. (A forward to reverse ratio of 100:1 is generally considered satisfactory.) Any reverse reading which is excessively lower than normally expected indicates a shorted transistor or at least a very large leakage current. If both the forward and reverse readings are near infinity, the transistor is open.

Another quick transistor test with an ohmmeter is as follows:

For PNP transistors, connect the negative lead of the ohmmeter to the collector of the transistor to be tested, and the positive lead to the emitter. Select a scale on the ohmmeter that gives approximately a midscale reading. Short the base to the emitter. An increase in the resistance reading on the meter indicates a good transistor. A decrease or no change in the reading indicates a faulty transistor. Both open and shorted transistors will indicate bad.

For NPN transistors—use the same procedure as for PNP, except connect the positive lead of the ohmmeter to the collector and the negative lead to the emitter.

CAUTION: "DEENERGIZE EQUIPMENT BEFORE PERFORMING IN-CIRCUIT TESTS



OPERATING INSTRUCTIONS

S2 PNP/NPN SWITCH	S1 FUNCTION	POS.	ACTIONS AND INDICATIONS	EQUIVALENT CIRCUITS
—	OFF	1	METER POINTER INDICATES EXACTLY ZERO Ⓐ. WHEN METER IS NOT IN USE, S1 SHOULD ALWAYS BE "OFF" TO AVOID UNNECESSARY DRAIN ON METER BATTERIES.	
BETA MEASUREMENTS (IN/OUT OF CIRCUIT)				
CORRESPONDS TO TYPE OF DEVICE UNDER TEST (DUT)	BETA CAL	2	PLUG TRANSISTOR IN TEST JACK, CBE (TRANSISTOR SOCKET J2); OR CONNECT TEST LEADS TO TRANSISTOR WITH YELLOW TO EMITTER, BLACK TO BASE, AND RED TO COLLECTOR. ADJUST "BETA CAL" CONTROL, R5, SO THAT METER INDICATES FULL SCALE.	
	BETA X1	3	METER INDICATES BETA DIRECTLY ON TOP SCALE. IF METER INDICATES BETA IS GREATER THAN 10, PLACE FUNCTION SWITCH S1 IN THE "BETA X 10" POSITION. (SEE NOTE)	
	BETA X 10	4	MULTIPLY THE METER INDICATION OF BETA BY 10 TO OBTAIN BETA. (SEE NOTE)	
ELECTRODE RESISTANCE MEASUREMENTS (IN CIRCUIT)				
—	OHMS E-B	5	CONNECT TEST LEADS TO TRANSISTOR - IN CIRCUIT - WITH YELLOW TO EMITTER, BLACK TO BASE, AND RED TO COLLECTOR. RESISTANCE APPEARING BETWEEN EMITTER AND BASE ELECTRODES IS INDICATED ON THE CENTER (RED) SCALE OF THE METER.	(SEE NOTE)
	OHMS C-B	6	RESISTANCE APPEARING BETWEEN COLLECTOR AND BASE ELECTRODES IS INDICATED ON THE CENTER (RED) SCALE OF THE METER.	
	OHMS C-E	7	RESISTANCE APPEARING BETWEEN COLLECTOR AND EMITTER ELECTRODES IS INDICATED ON THE CENTER (RED) SCALE OF THE METER.	
Ico MEASUREMENTS (OUT OF CIRCUIT)				
CORRESPONDS TO TYPE OF DEVICE UNDER TEST (DUT)	Ico OUT/CKT X1	8	PLUG TRANSISTOR IN TEST JACK, J2. METER INDICATES Ico DIRECTLY IN MICROAMPERES ON LOWEST SCALE. IF METER INDICATES OFF SCALE, PLACE FUNCTION SWITCH, S1, IN THE X10 POSITION.	
	Ico OUT/CKT X10	9	MULTIPLY THE METER INDICATION OF Ico BY 10 TO OBTAIN Ico. IF METER INDICATES OFF SCALE, REVERSE PNP/NPN SWITCH AND REPEAT POS. 8 TEST	
DIODE Ir MEASUREMENTS (OUT OF CIRCUIT)				
PNP	Ico OUT/CKT X1	8	CONNECT CATHODE OF DIODE TO RED TEST LEAD, AND ANODE OF DIODE TO BLACK TEST LEAD. METER INDICATES Ir DIRECTLY IN MICROAMPERES ON LOWEST SCALE. IF METER INDICATES OFF SCALE, PLACE FUNCTION SWITCH, S1, IN THE X10 POSITION.	
	Ico OUT/CKT X10	9	MULTIPLY THE METER INDICATION OF Ir BY 10 TO OBTAIN Ir. IF METER INDICATES OFF SCALE, REVERSE PNP/NPN SWITCH AND REPEAT POS. 8 TEST.	
DIODE IN CIRCUIT MEASUREMENTS				
PNP	DIODE IN/CKT	10	CONNECT CATHODE OF DIODE TO RED TEST LEAD, AND ANODE OF DIODE TO YELLOW TEST LEAD. INCREASE "BETA CAL" CONTROL UNTIL METER DEFLECTS UPSCALE. REVERSE PNP/NPN SWITCH IF METER DEFLECTS DOWNSCALE. NO DEFLECTION OF METER INDICATES THAT THE DIODE IS EITHER OPENED OR SHORTED, OR THAT THE RELATED CIRCUIT IMPEDANCE IS LESS THAN 20 OHMS.	
BATTERY CHECK				
—	BAT	11	IF BATTERIES ARE GOOD, METER INDICATES IN THE RED BOX LABELED "BAT".	

Ⓐ - ALIGNMENT PROCEDURE

NOTE: POSITIONS 5, 6, AND 7 ARE USED TO PRECLUDE FALSE INTERPRETATIONS OF IN-CIRCUIT BETA MEASUREMENTS, SINCE ACCURACY OF THE BETA X 1 RANGE IS [illegible] ONLY WHEN E TO B LOADING IS EQUAL TO OR GREATER THAN [illegible] OHMS; BETA X 10 IS [illegible] ONLY WHEN E TO B LOADING IS EQUAL TO OR GREATER THAN [illegible] OHMS.

26.237.2

Figure 17-17.—AN/USM-206 test set operating instructions.

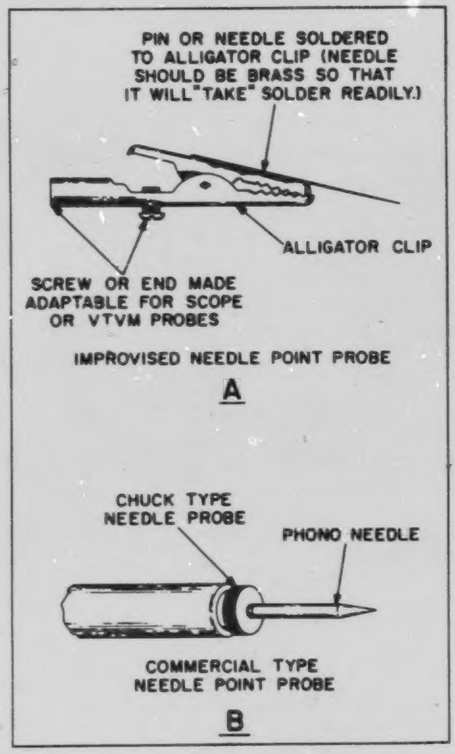
SERVICING PRECAUTIONS

Because of their reliability, transistors are usually soldered in the circuit. Removing and testing each transistor will not only unnecessarily subject the transistor to heating, but may also result in damage to some other component, particularly in the case of a printed circuit board. Transistors may be removed however, if the proper precautions are observed. Care must be taken to prevent damage to the transistor by the heat from the soldering iron. Also, the leads must be handled carefully as they are very brittle. Do not remove or replace a transistor while the battery or power source is connected.

Before removing a transistor for replacement, note the orientation of the collector, base, and emitter leads. Preshape and cut the leads of the new transistor to the proper length, using sharp cutters to prevent undue stress on the leads entering the transistor. Pigtail leads should have a minimum clearance of one-sixteenth inch between bend and transistor body. Shape any bend required in a gradual curve. Sharp (90°) bends are not acceptable. With the transistor properly positioned, solder the leads to the connections using the proper solder, soldering iron, and a heat sink.

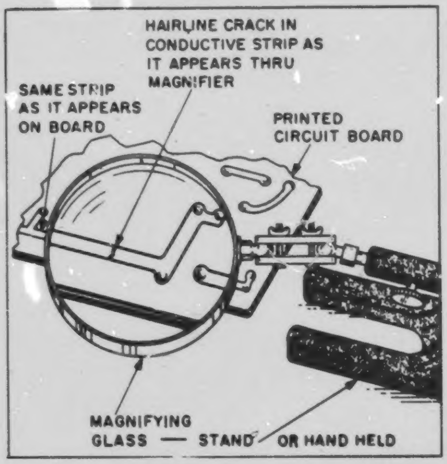
For stability of the electrical characteristics, the maintenance of the hermetic seal of the transistor must be emphasized. This seal in addition to maintaining the carefully controlled environment in which the transistor operates, also excludes moisture which causes instability.

Battery eliminators should not be used as the source of power for transistors or other semiconductor devices. Because of the low current drain of transistor circuits, the voltage regulation of battery eliminators is poor.


PIN OR NEEDLE SOLDERED TO ALLIGATOR CLIP (NEEDLE SHOULD BE BRASS SO THAT IT WILL "TAKE" SOLDER READILY.)
ALLIGATOR CLIP
SCREW OR END MADE ADAPTABLE FOR SCOPE OR VTVM PROBES
IMPROVISED NEEDLE POINT PROBE
A
CHUCK TYPE NEEDLE PROBE
PHONO NEEDLE
COMMERCIAL TYPE NEEDLE POINT PROBE
B

70.109

Figure 17-18.—Needle probes.


HAIRLINE CRACK IN CONDUCTIVE STRIP AS IT APPEARS THRU MAGNIFIER
SAME STRIP AS IT APPEARS ON BOARD
PRINTED CIRCUIT BOARD
MAGNIFYING GLASS — STAND OR HAND HELD

70.110

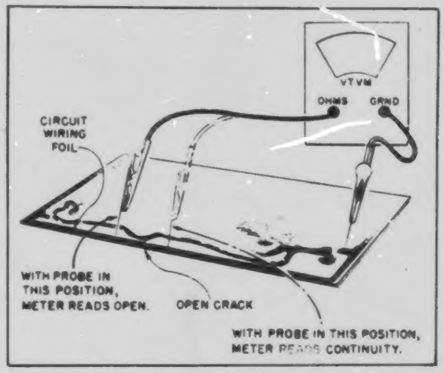
Figure 17-19.—Magnifying glass to locate hairline crack.

It should be remembered that temperature is the most important factor affecting transistor life, and that it is important to keep the ambient temperature as low as possible. It has been estimated that for every 10°C the junction temperature is lowered, the life of the transistor is doubled.

PRINTED CIRCUITS

Although the troubleshooting procedures for printed circuits are similar to those for conventional circuits, the repair of printed circuits requires considerably more skill and patience. The printed circuits are small and compact, and require special servicing techniques.

It is advisable to first check the defective printed circuit before beginning work on it to determine whether any prior servicing has been done. The defective part should be pinpointed by a study of the symptoms and by careful analysis of the circuit before attempting to trace trouble on a printed circuit board. Ascertain whether the conducting strips are coated with a protective lacquer, epoxy resin, or similar substance. If so, carefully scrape it away, or better still, use a needle or chuck type needle probe to penetrate the coating so that continuity checks can be made (fig. 17-18).


VTVM
OHMS
GRND
CIRCUIT WIRING FOIL
WITH PROBE IN THIS POSITION, METER READS OPEN.
OPEN CRACK
WITH PROBE IN THIS POSITION, METER READS CONTINUITY.

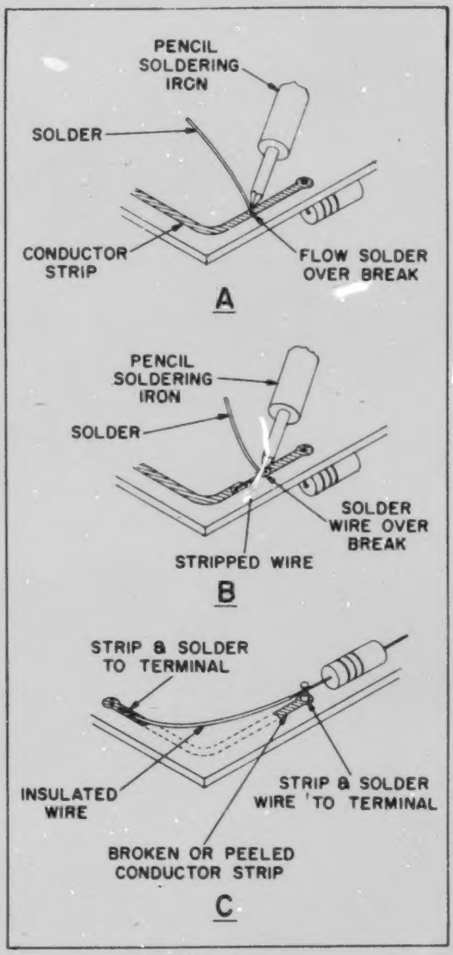
70.111
Figure 17-20.—Using VTVM to locate a break in a conductive strip.

Breaks in the conducting strip (foil) can cause permanent or intermittent trouble. In many instances these breaks will be so small that they cannot be seen with the naked eye. These almost invisible cracks (breaks) can be located readily with the aid of a hand- or stand-held magnifying glass (fig. 17-19).

The most common cause of an intermittent condition is poorly soldered connections. Other causes are broken boards, broken conducting strips, fused conducting strips, arc-over, and loose terminals.

To check out and locate trouble in the conducting strips of a printed circuit board, set up a multimeter (one which does not pass a current in excess of one ma) for making point-to-point resistance test using needle point probes (fig. 17-20). Insert one point into the conducting strip close to the end or terminal, and place the other probe on the terminal or opposite end of the conducting strip. The multimeter should indicate continuity. If the multimeter indicates an open circuit, drag the probe along the strip (or if the strip is coated, puncture the coating at intervals) until the multimeter indicates continuity. Mark this area and then use a magnifying glass to locate the fault as shown in figure 17-19.

If the break in the conducting strip is small, lightly scrape away any coating covering the area of the strip to be repaired. Clean the area with a firm bristle brush and solvent, then repair the cracked or broken area of the strip by flowing solder over the break (fig. 17-21A). If there is any indication that the strip might peel, bridge the break with a small section of bare wire approximately two inches in length, as shown in figure 17-21B. Apply solder along the entire length of the wire to bond it solidly to the conducting strip. Exercise care in applying the solder to prevent it from flowing onto or near an adjacent strip. Keep the solder within the limits of the strip being repaired.


PENCIL SOLDERING IRON
SOLDER
CONDUCTOR STRIP
FLOW SOLDER OVER BREAK
A
PENCIL SOLDERING IRON
SOLDER
SOLDER WIRE OVER BREAK
STRIPPED WIRE
B
STRIP & SOLDER TO TERMINAL
INSULATED WIRE
STRIP & SOLDER WIRE TO TERMINAL
BROKEN OR PEELED CONDUCTOR STRIP
C

70.112
Figure 17-21.—Three methods of repairing broken conducting strips.

If a conducting strip is burned out or fused, cut and remove the damaged strip. Connect a length of insulated wire across the break or from solder point to solder point as shown in figure 17-21C.

It is best not to glue or bond a conducting strip that has been lifted or peeled from the board at a terminal or solder point. Instead clip off the raised section and replace it with insulated hookup wire from solder point to solder point. Always check printed circuit boards carefully after repairs for solder droppings that may cause shorts.

Frequently, a low-resistance leakage path will be created by moisture or dirt that has carbonized onto the phenolic board. This leakage can be detected by measuring the suspected circuit with a multimeter. To correct this condition, clean the carbonized area with solvent and a stiff brush. If this does not remove it, use a scraping tool (spade end of a solder-aid tool or its equivalent) to remove the carbon, or drill a hole through the leakage path to break the continuity of the leakage. When the drilling method is used, be careful not to drill into a part mounted on the opposite side.

Most printed circuit boards have areas of conduction known as grounding conductors at each edge of the board, or on the parts-mounted side of the board. These grounding conductors are conducting strips used for grounding parts and as a mounting contact for the chassis or common ground. Occasionally an intermittent condition will result if the grounding screws or mounting screws become loose. If this occurs, tighten the screws and then solder a good bond directly from the grounding strip to the chassis or equipment ground. If this is not practical, bond the screws (after tightening) with an epoxy resin or similar compound.

The most common cause of broken boards is droppage. Some boards are broken because of careless handling during servicing. Be extremely careful at all times while handling a board. Do not flex the board indiscriminately; be especially careful when removing the board or replacing parts; do not force anything associated with the board. It is advisable to use a chassis-holding jig or vise when servicing printed circuit boards.

When a printed circuit board is broken it is better to replace the entire board. If the board is not too complicated, or the damage not too extensive however, the board can probably be repaired in an emergency, as discussed later.

Special Techniques

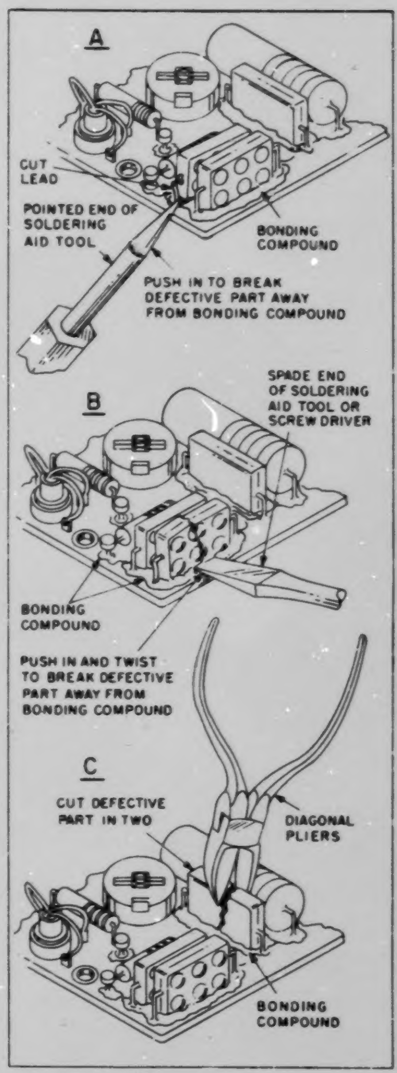
It is always desirable to replace parts on a printed circuit board without applying heat directly to the conducting strip. This procedure prevents damage to the printed circuit conductors, feed-through devices, eyelets, and terminals, and saves time in repair. It also prevents damage to semiconductors and other heat sensitive parts that may be in close proximity to the part being replaced.

Replacing parts requires that each type of part mounting be considered individually for the best methods of removal. A part to be removed may be too close to a heat sensitive semiconductor or other part to allow the hot soldering iron to be applied. A quick test to determine the safe distance is to place your finger between the semiconductor (or heat sensitive part) and the part to be removed. Place the hot soldering iron in the position to be used. If the heat is too great for your finger, it is too hot for the semiconductor. If this is the case, place a shield (asbestos or similar substance) between the parts before applying the hot soldering iron, and place heat sink clamps on all leads from the heat sensitive part.

Solid-state parts and their associated circuitry are extremely sensitive to thermal changes. Heat sinks and shunts must be applied with shields inserted to protect the associated parts any time repair or removal of a part requires the use of a hot soldering iron.

Removal of an axial lead part (a part mounted by leads that extend from each end, such as a common resistor or capacitor) that has been bonded to a printed circuit board can be accomplished by breaking the defective part or by applying heat to the bonding compound. The method to be used depends upon the part itself and its location. If the part cannot be removed by heat, cut or break the part away from the bonding compound. Figure 17-22 shows two methods of breaking the part away from the bonding compound where the part is too close to other parts to use cutting pliers. In some instances, the part to be replaced is so closely positioned between other parts that one lead must be cut close to the body of the defective part to permit application of the prying tool. When possible, cutting the defective part with end-cutting pliers or diagonals (as shown in part C fig. 17-22) is the preferred method to use.

Regardless of which tool is used (round pointed or spade type, parts A and B Fig. 17-22), great care must be used in its application


A
CUT LEAD
POINTED END OF SOLDERING AID TOOL
BONDING COMPOUND
PUSH IN TO BREAK DEFECTIVE PART AWAY FROM BONDING COMPOUND
B
SPADE END OF SOLDERING AID TOOL OR SCREW DRIVER
BONDING COMPOUND
PUSH IN AND TWIST TO BREAK DEFECTIVE PART AWAY FROM BONDING COMPOUND
C
CUT DEFECTIVE PART IN TWO
DIAGONAL PLIERS
BONDING COMPOUND

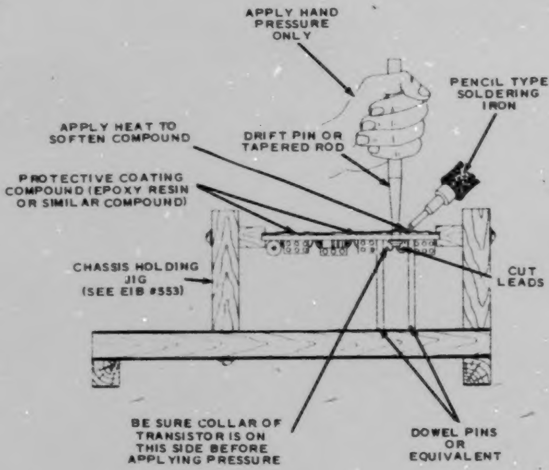
70.113

Figure 17-22.—Removing a defective part from bonding compound.

to prevent the printed circuit board or other parts from being damaged. Apply the point of the tool against the bonding compound between the part and the printed circuit board. Use the tool in such a way that it works away the bonding compound from the part to be broken away, until enough has been removed for the tool to exert pressure against the part. Keep the leverage surface area of the tool flat against the surface of the printed circuit board; this helps to prevent the tool from gouging or breaking the board. Never apply heavy pressure against a printed circuit board.

After the defective part has been removed from the bonding compound, remove the leads or tabs from their terminals on the printed circuit board. Clean the area thoroughly before installing the new part. Do not remove the compound left on the board under the removed part unless its condition requires it. The mold left in the compound should be the same as the new part; thus inserting the new part in this mold helps to secure it from vibration. After the repairs have been completed and the circuit tested, spray the newly soldered area with an insulating varnish or equivalent. Coat the new part or parts with a bonding compound.

To replace a defective transistor, first cut all its leads then remove it from the assembly. Transistors are mounted on printed circuit boards in many different ways; thus it is necessary to study how a particular transistor is secured before attempting to remove it. A transistor with clamp type mounting requires only a pointed tool between the clamp and the transistor to remove it. A transistor mounted in a socket may have a wire or spring clamp around it. Remove this clamp before pulling


APPLY HAND PRESSURE ONLY
PENCIL TYPE SOLDERING IRON
APPLY HEAT TO SOFTEN COMPOUND
DRIFT PIN OR TAPERED ROD
PROTECTIVE COATING COMPOUND (EPOXY RESIN OR SIMILAR COMPOUND)
CHASSIS HOLDING JIG (SEE EIB #553)
CUT LEADS
BE SURE COLLAR OF TRANSISTOR IS ON THIS SIDE BEFORE APPLYING PRESSURE
DOWEL PINS OR EQUIVALENT

70.114

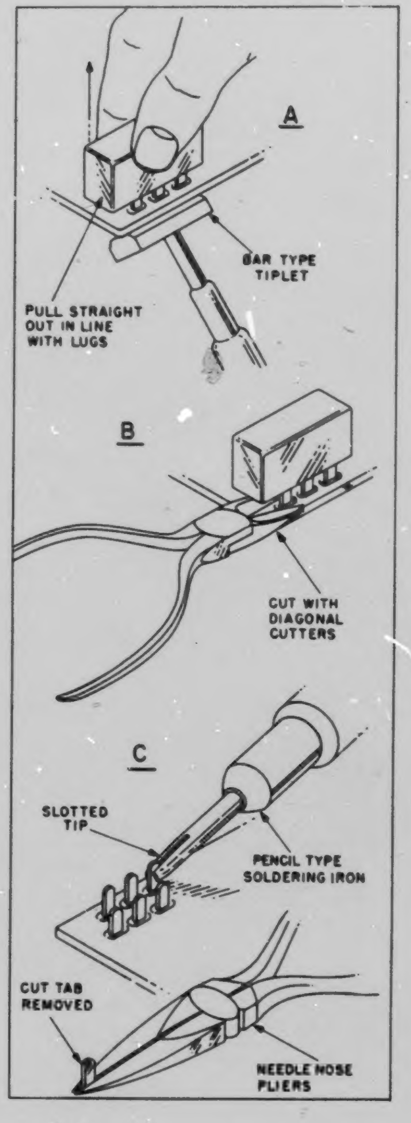
Figure 17-23.—Removing a transistor.

the transistor out of the socket. In some instances the transistor is bolted through the board. Remove the nut and washer, then remove the transistor. Where vibration is a prime factor, the manufacturer mounts the transistor through the circuit board and bonds it with epoxy resin or a similar compound. For this type, a flat-ended round rod type tool of a diameter less than that of the transistor case is required. Be sure that the printed circuit board on which the transistor is mounted is secured in a proper device, and in such a way that pressure exerted against the board will be relieved by a proper support on the other side (fig. 17-23). Apply a hot soldering iron to the bonding compound and simultaneously apply the tool against the top of the transistor exerting enough pressure to remove the transistor from the softened compound and then on through and out the board (fig. 17-23).

Before installing the new transistor, care must be taken to prepare the part for installation. Test the transistor in a transistor tester before installing, as transistors can become defective in storage. Preshape and cut the new transistor leads to the shape and length required for easy replacement. Use sharp cutters and do not place undue stress on any lead entering the transistor. The leads are fragile and are susceptible to excessive bending or too sharp a bend as mentioned previously. A safety measure to ensure that the lead will not break off at the base is to use two pairs of needle-nose pliers. With one pair grasp the lead close to the transistor base while shaping the rest of the lead with the other pair.

After the remaining pieces of the defective transistor terminal leads have been removed and the terminals on the board are cleaned, connect the new transistor to its proper terminals. Test the circuit to ensure that it is operative, then rebond the transistor. Do not use heat to rebond replaced transistors or other semiconductors.

To remove and replace a multilug part such as a transformer, choke, filter, or other similar potted, canned, or molded part, release the part from its mounting before disconnecting or cutting its conductors. Before applying pressure to remove such a part, inspect it carefully to be sure that the part is completely free of all its connections to the printed circuit board, and that all bent or twisted mounting lugs have been straightened; otherwise you may break the board by applying pressure to it. Do not wrench or twist a multilug part to free it, as this may cause the conducting strip to become unbonded from the board. Work this type of part in and out in line with its lugs, while applying a hot soldering iron using a bar type tiplet adapter or similar tool as shown in figure 17-24A.

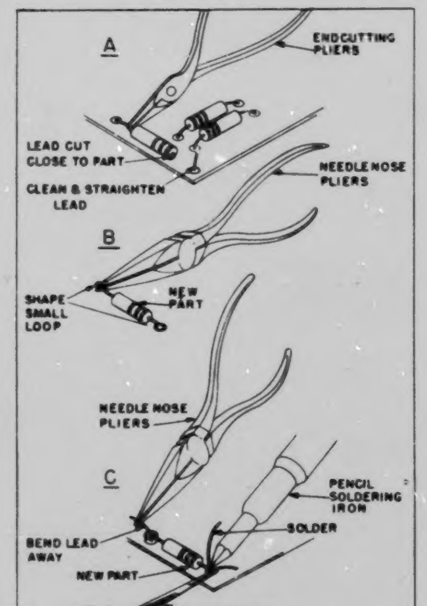

A
BAR TYPE TIPLET
PULL STRAIGHT OUT IN LINE WITH LUGS
B
CUT WITH DIAGONAL CUTTERS
C
SLOTTED TIP
PENCIL TYPE SOLDERING IRON
CUT TAB REMOVED
NEEDLE NOSE PLIERS

70.115
Figure 17-24.—Removing a defective multilug part.

When possible cut the conducting or mounting leads and lugs of the defective multilug part on the mounting side of the board (fig. 17-24B). Heat and straighten the clipped leads with a hot soldering iron and slotted soldering-aid tool (or slotted soldering iron tiplet or similar desoldering tool) applied to the circuit side of the board; pull the leads or tabs through with pliers as shown in figure 17-24C.

To replace the new multilug part, check to be sure that all of the lead holes or slots are free and clean, allowing easy insertion of the multilug part. Do not force the part; if it does not position easily, check and rework the terminals and holes or slots until it does seat freely, then proceed to solder.

Be very careful when replacing defective parts that have leads terminating on standoffs, feed-through terminals, etc. In most cases, standoffs and feed-through terminals are very small and are mounted on a thin phenolic board; thus they are very susceptible to damage by heat and undue pressure.


A
ENDCUTTING PLIERS
LEAD CUT CLOSE TO PART
CLEAN & STRAIGHTEN LEAD
NEEDLE NOSE PLIERS
B
SHAPE SMALL LOOP
NEW PART
NEEDLE NOSE PLIERS
C
PENCIL SOLDERING IRON
SOLDER
BEND LEAD AWAY
NEW PART
HEAT SINK (HEMOSTATS)

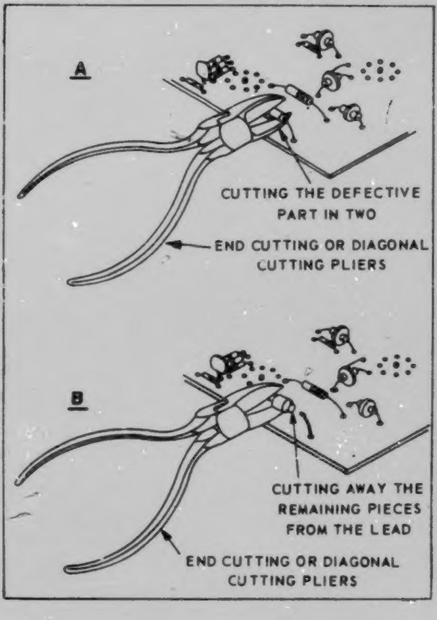
70.116

Figure 17-25.—Replacing defective parts by cutting leads.

Emergency Techniques

In many instances there is a need for a time-saving technique and procedure for emergency repair. It is desirable when making an emergency repair, to avoid unnecessary disassembly to expose the defective part when testing and/or repairing. In many instances this can be accomplished by removing only the cover from the unit to be repaired.

To remove and replace an axial lead part, cut the leads as close as possible to the body of the part, then connect the leads of the replacement part to the leads remaining on the board. The cutting is accomplished with a pair of end-cutting pliers (fig. 17-25A). Clean and straighten the leads remaining on the board. Fashion small loops in the leads of the replacement part (fig. 17-25B), making the loop size and lead length such that the loops slip easily over the leads projecting from the board. Secure these connections by bending the old leads away from the part. Place a heat sink clamp on the lead from the board, between the board and the connection to be soldered, then solder the

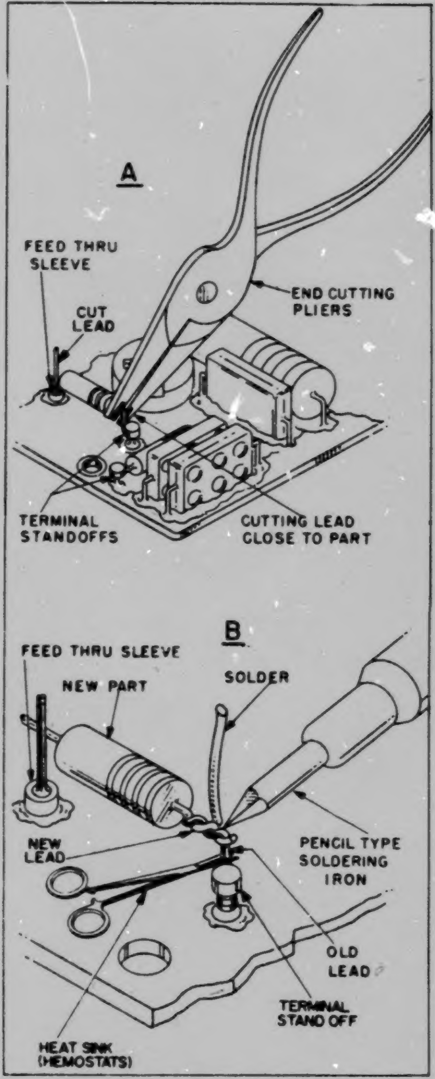

A
CUTTING THE DEFECTIVE PART IN TWO
END CUTTING OR DIAGONAL CUTTING PLIERS
B
CUTTING AWAY THE REMAINING PIECES FROM THE LEAD
END CUTTING OR DIAGONAL CUTTING PLIERS

70.117

Figure 17-26.—Cutting for maximum lead length.

connection (fig. 17-25C). The heat sink prevents the leads connected to the board from becoming unsoldered and causing a short or open circuit. Check to ensure that the old leads are still properly connected to the conducting strip.

If cutting the leads of a defective axial lead part would result in leads that are too short for the replacement part to be connected properly, cut the defective part in half with a pair of diagonal or end-cutting pliers (fig. 17-26A). Then carefully cut away the pieces of the part from each lead (fig. 17-26B). This will yield leads of sufficient length to permit the replacement part to be fitted and soldered.



70.118

Figure 17-27.—Removing part from standoff terminal.

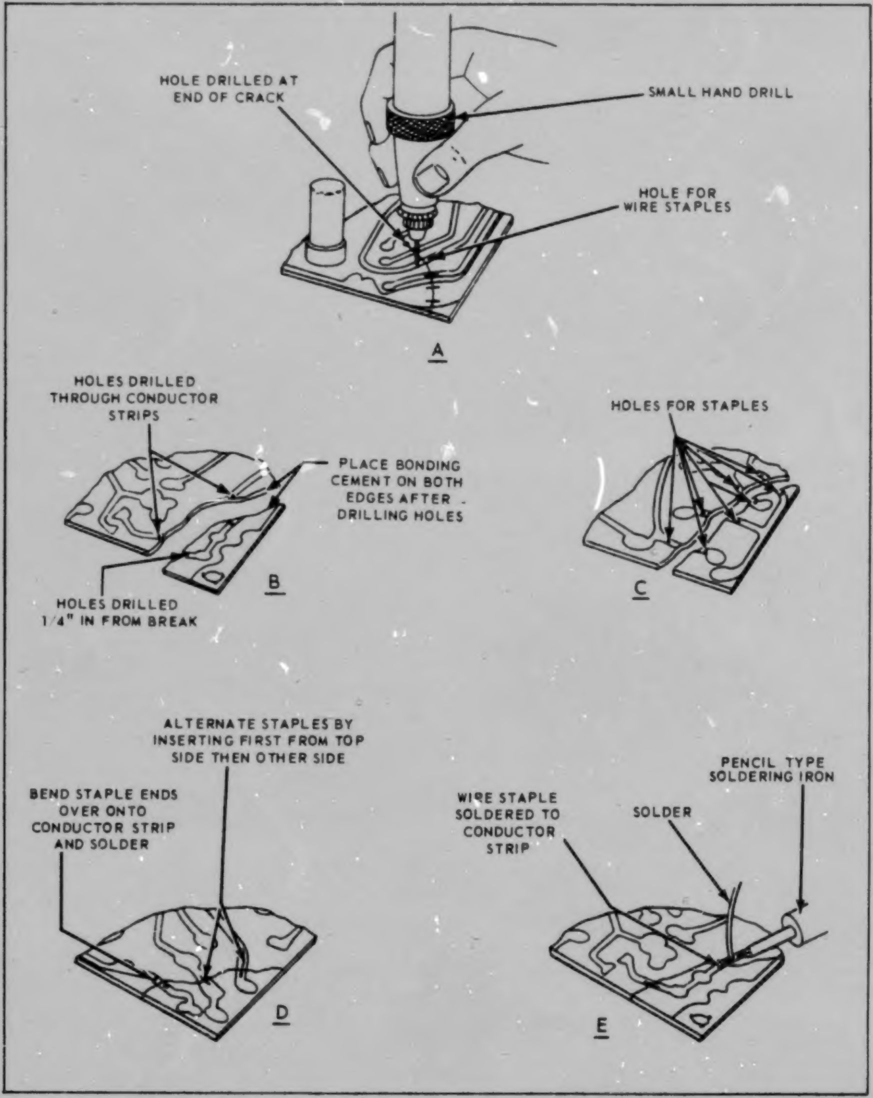
Care must be taken when replacing a defective part that terminates on miniaturized standoffs and feed-through terminals as stated previously. For emergency or temporary repair purposes, the following techniques may be used. Cut the lead close to the defective part as shown in figure 17-27A. Use a heat-sink clamp or pliers next to the terminal, then solder a spliced lead from the terminal to the new part (fig. 17-27B).

A helpful heat control technique is to place a small piece of beeswax on the terminal behind the heat sink. When the beeswax melts, the temperature limit has been reached, and the soldering iron must be removed immediately. Allow the area to cool before attempting to complete the soldering of the connection. Apply a new piece of beeswax to the terminal, repeating this procedure until the connection is satisfactorily soldered.

A broken printed circuit board may have to be repaired in an emergency, where no replacement is available. If the board is not completely broken but is only cracked, drill a hole at the end of each crack (fig. 17-28A), to prevent further lengthening of the crack. Then repair the crack by placing a conductive material across the defective area.

If a small portion or corner of the board is broken off, it may be rebonded with a nonconductive cement or its equivalent. If cementing is not practical, or does not hold satisfactorily, the pieces can be fastened together with wire staples cut from solid conducting wire of the diameter and length required, depending upon the width of the conducting strip to be repaired.

To insert the staples, drill holes about 1/4 inch in from each side of the break (fig. 17-28 B & C). The holes should be just large enough to accommodate the wire used for stapling. Drill the holes through the conducting strips so that the staples will provide a good electrical contact across the break. This method will permit the use of enough staples to hold the pieces together without danger of shorts between conductors. If the break is sufficiently large, position additional staples at all points possible to give the board more support.


HOLE DRILLED AT END OF CRACK
SMALL HAND DRILL
HOLE FOR WIRE STAPLES
A
HOLES DRILLED THROUGH CONDUCTOR STRIPS
PLACE BONDING CEMENT ON BOTH EDGES AFTER DRILLING HOLES
HOLES DRILLED 1/4" IN FROM BREAK
B
HOLES FOR STAPLES
C
ALTERNATE STAPLES BY INSERTING FIRST FROM TOP SIDE THEN OTHER SIDE
BEND STAPLE ENDS OVER ONTO CONDUCTOR STRIP AND SOLDER
D
PENCIL TYPE SOLDERING IRON
WIRE STAPLE SOLDERED TO CONDUCTOR STRIP
SOLDER
E

70.119

Figure 17-28. — Repairing a broken printed circuit board.

Where the methods described above do not provide structural strength or sufficient rigidity, splints or a doubler may be used. Strips of thin card material are glued across the crack with a nonconductive adhesive. Where needed, additional strength may be obtained by gluing a plate of the card material to the splints with the nonconductive adhesive.

Rebond any loose conducting strips with a nonconductive bonding cement, then apply nonconductive cement to both sides of the break, and join the sections together. Insert half of the measured and precut wire staples from bottom to top, bending the ends flush against the board (fig. 17-28D). Solder these staples to the conducting strip (fig. 17-28E).

After the repairs are completed, clean both sides of the repaired area with a stiff brush and solvent. Allow the board to dry thoroughly, then coat the repaired area with an epoxy resin or similar compound. This coating protects and strengthens the repaired area.

TROUBLESHOOTING AIDS

Basically the purpose of corrective maintenance is to restore a system's operation to acceptable standards. To do this you must learn the operation and the standards of the system. Firsthand knowledge of the operation can be obtained by performing the tests and the preventive maintenance. Instruction books supply detailed information on the system's operation as well as the functions of the major units in the system. These books contain a variety of maintenance-oriented diagrams to assist you in troubleshooting IC equipment.

ONE-FUNCTION DIAGRAMS

These diagrams or drawings show the internal and interconnecting circuitry between all parts of the system. A single illustration depicts all circuits involved in one particular function (quantity or signal) of a system. This eliminates the need for using many separate diagrams for each of the equipments involved in the particular function. Circuit information is displayed by functional flow from left to right. The unit in which the signal originates is on the left of the drawing, the unit that ultimately receives the signal is to the right. All major equipments, terminal boards, patch panels, dials, plugs, and other electrical components are labeled.

These one-function diagrams are not only an aid in troubleshooting but they provide a key to the understanding of the entire system.

SERVICING BLOCK DIAGRAMS

These troubleshooting aids should enable you to see the relationships between circuits and components. Also, you can determine the general locations of the test points for checking the condition of the equipment. A servicing block diagram should aid you in localizing the trouble to a small segment.

SCHEMATIC DIAGRAMS

A schematic diagram shows how the parts of a circuit are connected for the operation of the equipment. It does not tell how the parts look, or how they are constructed. Each component is illustrated by a symbol. A set of schematics enables the technician to trace the passage of energy throughout the entire equipment. The detail of each circuit is drawn. This enables the technician to determine, by test, the operating condition of each part and connection.

VOLTAGE DISTRIBUTION DIAGRAMS

These diagrams trace the distribution of the supply voltages throughout the equipment. The diagrams show all the relays, contacts, switches, and access points for that particular voltage distribution.

VOLTAGE AND RESISTANCE CHARTS

These charts show the normal voltage and resistance values at the pins of connectors and tube sockets. Voltage and resistance charts are used to pinpoint the faulty element after it has been isolated through the use of troubleshooting charts and servicing diagrams. After isolating the source of trouble to a stage or area of a circuit, determine which chart you should use. Generally, there is one for each chassis in the equipment. Using servicing diagrams for reference, check voltage in the circuit starting with the input stage and continuing until the output is reached. Repeat this procedure for resistance measurements. When an abnormal indication is observed, discontinue the procedure and check the component or components involved to pinpoint the trouble. However, keep in mind that various controls will affect voltage and resistance readings: if a faulty reading is obtained, these controls should be checked for their proper settings.

SYMBOLIC INTEGRATED MAINTENANCE MANUAL (SIMM)

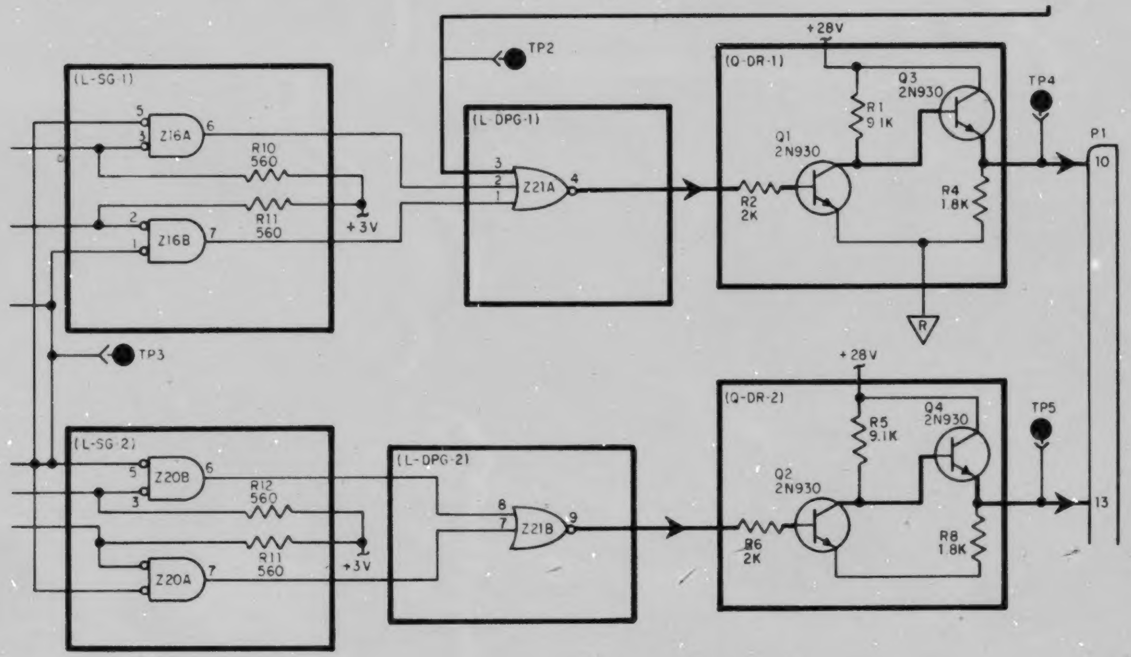
The IC Electrician is responsible for the maintenance of many different types of complex electrical/electronics equipment. Usually, the diagnostic logic shortcomings of his young maintenance force result in longer than necessary equipment downtimes. In some cases equipment damage is introduced by trial - and - error maintenance actions. Besides, some faults cannot be located and repaired by the unit level maintenance personnel because they lack experience or are not familiar with the equipment. Then too, personnel of all experience levels are frequently transferred and encounter new equipment. A relatively new troubleshooting aid, the Symbolic Integrated Maintenance Manual (SIMM), should help the troubleshooter identify more readily the general location of a fault. Though this manual presents a rather complete circuit analysis, in no way does it preclude the requirement for logical analysis and a well informed technician.

The Symbolic Integrated Maintenance Manual represents a major change in the methods of presenting technical data and the methods of diagnosing electronic system faults. Through the use of new information display techniques and symbology, blocks, and color shading, the job of fault isolation in complex electronic systems is made easier, faster, and surer.

The overall objective of the SIMM is to display more descriptive and illustrative data per page; eliminate unnecessary words, discussion, and illustrations; organize all required data so that rapid access is afforded; and display complete circuit element dependencies as simply as possible.

The SIMM helps organize the technical details of an equipment or system, providing users with all information they need to learn to operate and maintain the equipment or system. The style of writing and the use of circuit-identifier codes (coding that assists recognition of the circuit character) and coded symbols enables the trainee to learn faster. Circuit diagrams and associated text are presented on facing pages.

The text is concise; yet it defines the circuit operation precisely. Block diagrams relate the level of physical containment (unit, assembly, subassembly, sub-subassembly) within the hardware to the functional circuits. Associated text is likewise presented on a facing page. Coded symbols and abbreviations indicate the kind of signals being processed, and circuit-identifier codes identify the circuit represented by uniquely shaped blocks. Maintenance dependency charts, based upon positive logic, provide a



162.151(140B)

Figure 17-29.—Blocked schematic.

unique, fast method of trouble analysis, include operating procedures, and reveal to a degree the designed-in equipment maintainability. The emphasis on symbology, a concise writing style, and memory devices permit a reduction in page count with no loss in technical content.

The SIMM is developed around three basic building blocks:

1. Blocked Schematic
2. Blocked Text
3. Precise Access Blocked Diagram

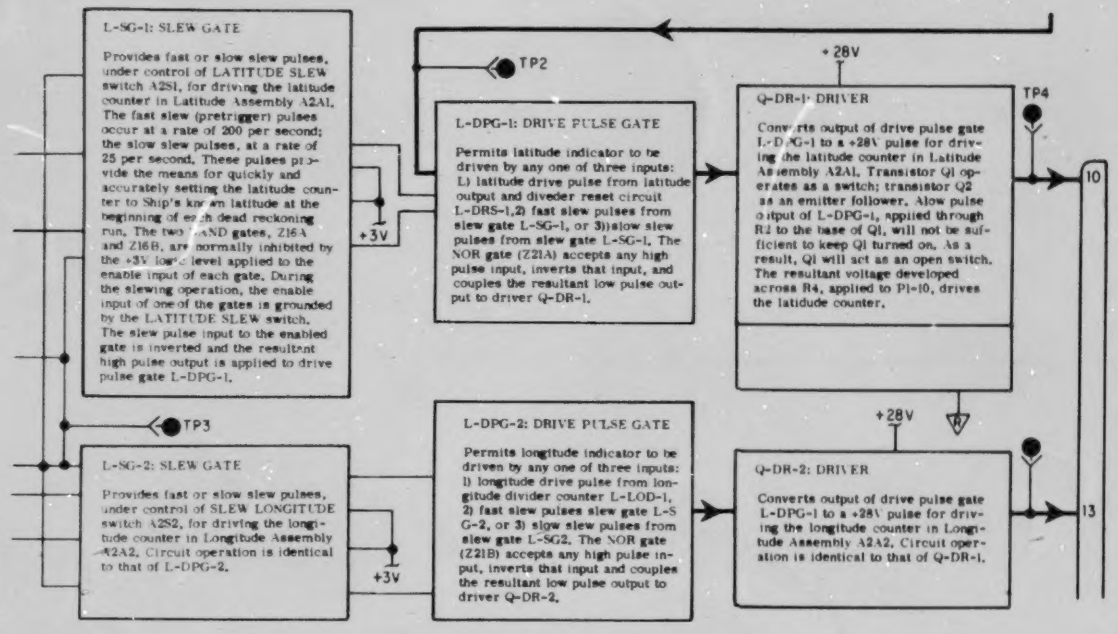
BLOCKED SCHEMATIC

By definition, a blocked schematic is a schematic diagram laid out in block form (fig. 17-29). It distinguishes the functions and physical aspects of the hardware by using shaded areas of blue and shaded areas of gray. The blue-shaded areas denote the functional features of a circuit (lowest definable basic circuit, filter, voltage divider, oscillator, amplifier, relay contact, meter, coil, switch, etc) and the gray-shaded areas denote the hardware (chassis, drawer, module, etc).

Each blue area includes ALL circuit elements that are involved in accomplishing the circuit function; these areas are called functional entities. Each functional entity is easily and simply identified by a circuit-identifier code, such as Q-DR-1 or L-DPG-2. For example, in Q-DR-1 (a driver stage), Q is the active element (a transistor); DR is the abbreviation for driver; and (1) indicates the first occurrence of that type of functional entity in the assembly. Functional entities are connected by signal flow lines which show the kinds of signals being processed by the coded shape of arrowhead superimposed on the lines.

BLOCKED TEXT

The blocked text (fig. 17-30) is presented on a page facing the blocked schematic. The arrangement of the blocked text matches that of the blocked schematic. Notice that the concise text of high information content per word, suitable to the functional entity being described, replaces



L-SG-1: SLEW GATE

Provides fast or slow slew pulses, under control of LATITUDE SLEW switch A2S1, for driving the latitude counter in Latitude Assembly A2A1. The fast slew (pretrigger) pulses occur at a rate of 200 per second; the slow slew pulses, at a rate of 25 per second. These pulses provide the means for quickly and accurately setting the latitude counter to Ship's known latitude at the beginning of each dead reckoning run. The two NAND gates, Z16A and Z16B, are normally inhibited by the +3V logic level applied to the enable input of each gate. During the slewing operation, the enable input of one of the gates is grounded by the LATITUDE SLEW switch. The slew pulse input to the enabled gate is inverted and the resultant high pulse output is applied to drive pulse gate L-DPG-1.

L-DPG-1: DRIVE PULSE GATE

Permits latitude indicator to be driven by any one of three inputs: L) latitude drive pulse from latitude output and diveder reset circuit L-DRS-1,2) fast slew pulses from slew gate L-SG-1, or 3))slow slew pulses from slew gate L-SG-1. The NOR gate (Z21A) accepts any high pulse input, inverts that input, and couples the resultant low pulse output to driver Q-DR-1.

Q-DR-1: DRIVER

Converts output of drive pulse gate L-DPG-1 to a +28V pulse for driving the latitude counter in Latitude Assembly A2A1. Transistor Q1 operates as a switch; transistor Q2 as an emitter follower. Alow pulse output of L-DPG-1, applied through R2 to the base of Q1, will not be sufficient to keep Q1 turned on. As a result, Q1 will act as an open switch. The resultant voltage developed across R4, applied to P1-10, drives the latidude counter.

L-SG-2: SLEW GATE

Provides fast or slow slew pulses, under control of SLEW LONGITUDE switch A2S2, for driving the longitude counter in Longitude Assembly A2A2. Circuit operation is identical to that of L-DPG-2.

L-DPG-2: DRIVE PULSE GATE

Permits longitude indicator to be driven by any one of three inputs: 1) longitude drive pulse from longitude divider counter L-LOD-1, 2) fast slew pulses slew gate L-SG-2, or 3) slow slew pulses from slew gate L-SG2. The NOR gate (Z21B) accepts any high pulse input, inverts that input and couples the resultant low pulse output to driver Q-DR-2.

Q-DR-2: DRIVER

Converts output of drive pulse gate L-DPG-1 to a +28V pulse for driving the longitude counter in Longitude Assembly A2A2. Circuit operation is identical to that of Q-DR-1.

162.152(140B)

Figure 17-30.—Blocked text.

the circuit elements in the respective blue-shaded area. Paragraph numbers, references to illustrations, complete sentence structure, and formal grammatical rules are not normally necessary to impart all needed information. Also, the use of facing pages and the similar block arrangements of text and functional entities enables a rapid association between text and blocks, text and circuit detail, and circuit detail and blocks. Like the blocked schematic, each blue-shaded area functional entity includes a circuit-identifier code for identification of the functional entity being described. However, the greatest value of this code is realized on high-level diagrams where much information must be confined to a small space.

PRECISE-ACCESS BLOCKED DIAGRAM

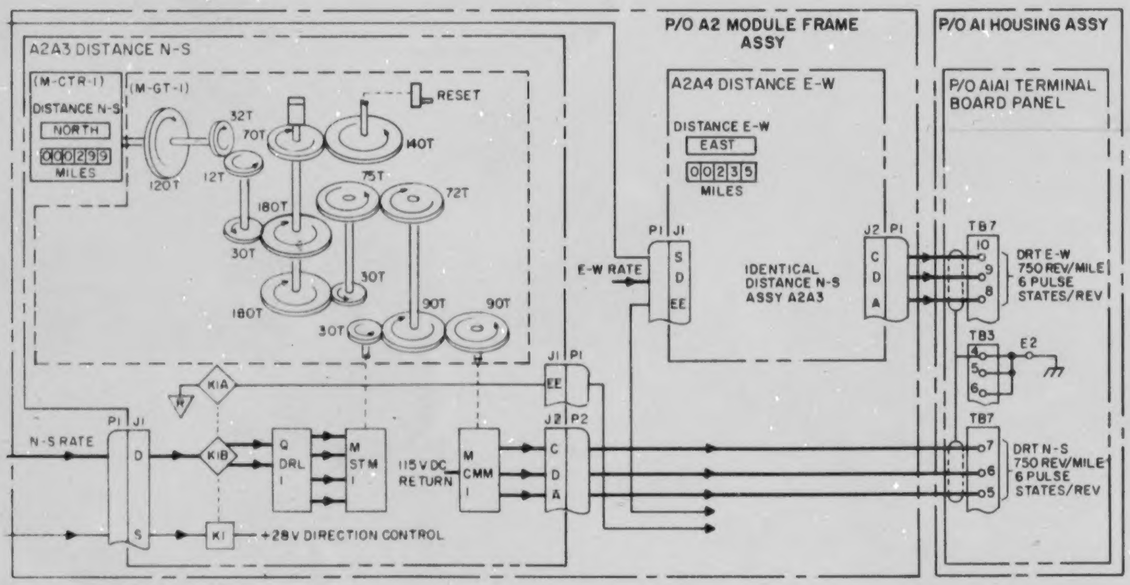
A precise-access blocked diagram is the next higher level diagram (fig. 17-31). It emphasizes levels of physical containment (units, assemblies, etc) of the functional entities with respect to their enclosures. Four basic shapes are used as symbols on this diagram to show the kind of functional entity through which the signal is being processed. These symbols are shown in table 17-1.

In each basic shape is inscribed the circuit-identifier code which identifies the actual functional entity. In addition, the coded arrows superimposed on the signal-flow lines which tie these shapes together are again used to identify the signals being processed. Also superimposed over these block diagrams are shades of gray that indicate the level of containment of the functional entities or other circuit elements in the equipment through which the signal or signals pass. Again there is blocked text on the facing page (fig. 17-32).

Detailed cabling information between all assemblies is shown on the precise-access blocked diagram. However, in cases of complex large equipments, power circuit cabling is detailed on power distribution diagrams.

OPERATING PROCEDURES

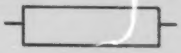
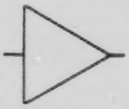
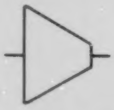
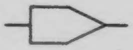
Procedures that explain how to operate equipment under normal and emergency conditions are included. Manuals for some equipment contain an operating chart that establishes a turn-on and


A2A3 DISTANCE N-S
(M-CTR-1)
DISTANCE N-S
NORTH
000299
MILES
(M-GT-1)
RESET
32T
70T
140T
120T
12T
75T
72T
180T
30T
30T
180T
90T
90T
30T
KIA
R
J1
P1
EE
P1
J1
N-S RATE
D
S
KIB
Q
DRL
1
M
STM
1
115 V DC
RETURN
M
CMM
1
J2
P2
C
D
A
K1
+28 V DIRECTION CONTROL
P/O A2 MODULE FRAME ASSY
A2A4 DISTANCE E-W
DISTANCE E-W
EAST
00235
MILES
P1
J1
E-W RATE
S
D
EE
IDENTICAL DISTANCE N-S ASSY A2A3
J2
P1
C
D
A
P/O A1 HOUSING ASSY
P/O A1A1 TERMINAL BOARD PANEL
TB7
10
9
8
DRT E-W 750 REV/MILE 6 PULSE STATES/REV
TB3
4
5
6
E2
TB7
7
6
5
DRT N-S 750 REV/MILE 6 PULSE STATES/REV

162.153(140B)

Figure 17-31.—Precise access block diagram.

Table 17-1.—Functional Symbols used on Precise Access Block Diagrams

	INCLUDES ALL TYPES OF CIRCUIT ELEMENTS OTHER THOSE SPECIFIED BELOW.
	CIRCUIT WHICH CHANGES THE VOLTAGE OR POWER LEVEL OF THE INCOMING SIGNAL. CIRCUIT MAY CONSIST OF AMPLIFIER STAGES. POWER AMPLIFIERS, EMITTER FOLLOWERS, ETC. THESE CIRCUITS ALWAYS CONTAIN ONE OR MORE NONLINEAR ACTIVE ELEMENTS SUCH AS TRANSISTERS.
	CIRCUIT WHICH GENERATES A SIGNAL OR PROCESSES AN INCOMING SIGNAL IN SOME MANNER OTHER THAN TO CHANGE SIGNAL VOLTAGE OR POWER LEVEL. EXAMPLES ARE OSCILLATORS, CONSTANT CURRENT REGULATORS, ETC. THESE CIRCUITS ALWAYS CONTAIN ONE OR MORE NONLINEAR ELEMENTS WHICH MAY BE ACTIVE (TRANSISTOR) OR PASSIVE (SEMICONDUCTOR DIODE).
	SWITCH

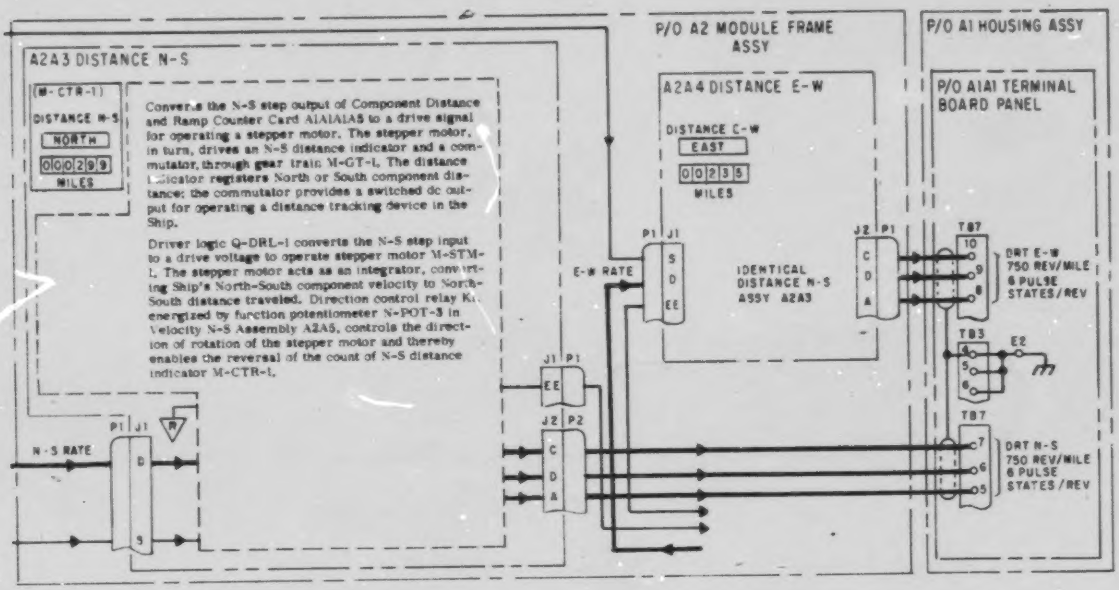
140.175

checkout procedure. The chart displays chronologically on the minimum number of pages all indications that can be recognized from outside the equipment. The indications are events, such as meter readings, lights, synchro rotating, or motor running noise, that can be recognized by the human senses. Shaded bands stretching across the chart denote the time lapse between events. All simultaneous events for a given step of the procedure appear on one horizontal line. Monitors are indicated in a solid black background box with white lettering.

Front panel indicators and other recognizable indications with front panel markings, as applicable, and their associated cabinet nomenclature are located along the top of the chart. If an event fails to happen, fault isolation is simplified by the indexing on the operator's chart. This indexing will lead the troubleshooter to the proper maintenance dependency chart and the circuit chain upon which the missing event depends. The troubleshooter merely associates the operational step and the event that did not occur to find the pertinent circuit chain. A vertical column on the left side of the page contains the turn-on procedure in a sequence of steps consistent with the engineering designed plan of turn-on. Also in the left-hand column, boxed and indented, are checkout procedural steps that can be performed at any time during operation. These checkout steps will give an indication of the functional section performance and will provide a sound basis for selection of operator preventive-maintenance checks.

MAINTENANCE DEPENDENCY CHART

One of the most important features of the SIMM is its troubleshooting tool, the Maintenance Dependency Chart (MDC). In addition to front panel marked indicators displayed across the top of the page, it contains the various assemblies, functional entities, or circuit elements through which a signal passes, as well as their chassis or cabinet locations. Each horizontal line results in an action, such as a lamp lighting, a synchro rotating, a meter indicating, or an indication of signal availability. These actions are referred to as events. Each horizontal line (event line) is a representation of the circuit that develops the event on its line. The maintenance dependency chart has the


A2A3 DISTANCE N-S
(M-CTR-1)
DISTANCE N-S
NORTH
000299
MILES
N-S RATE
P1
J1
D
S
R
J1
P1
EE
J2
P2
C
D
A
P/O A2 MODULE FRAME ASSY
A2A4 DISTANCE E-W
DISTANCE E-W
EAST
00235
MILES
E-W RATE
P1
J1
S
D
EE
IDENTICAL DISTANCE N-S ASSY A2A3
J2
P1
C
D
A
P/O A1 HOUSING ASSY
P/O A1A1 TERMINAL BOARD PANEL
TB7
10
9
8
DRT E-W 750 REV/MILE 6 PULSE STATES/REV
TB3
4
5
6
E2
TB7
7
6
5
DRT N-S 750 REV/MILE 6 PULSE STATES/REV

Converts the N-S step output of Component Distance and Ramp Counter Card A1A1A1A5 to a drive signal for operating a stepper motor. The stepper motor, in turn, drives an N-S distance indicator and a commutator, through gear train M-GT-1. The distance indicator registers North or South component distance; the commutator provides a switched dc output for operating a distance tracking device in the Ship.

Driver logic Q-DRL-1 converts the N-S step input to a drive voltage to operate stepper motor M-STM-1. The stepper motor acts as an integrator, converting Ship's North-South component velocity to North-South distance traveled. Direction control relay K1, energized by function potentiometer N-POT-3 in Velocity N-S Assembly A2A5, controls the direction of rotation of the stepper motor and thereby enables the reversal of the count of N-S distance indicator M-CTR-1.

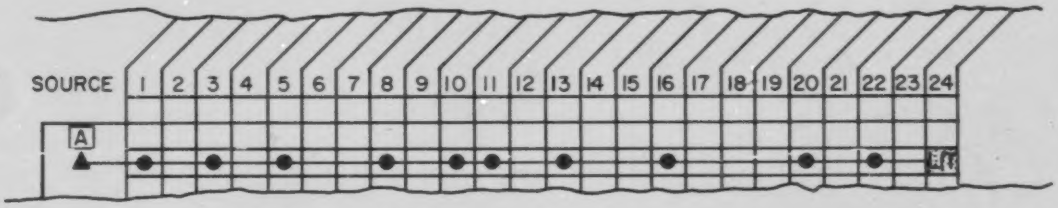
162.154(140B)

Figure 17-32.—Precise access blocked text.

unique advantage of permitting the simple display, in a limited space, of many events and their relationships.

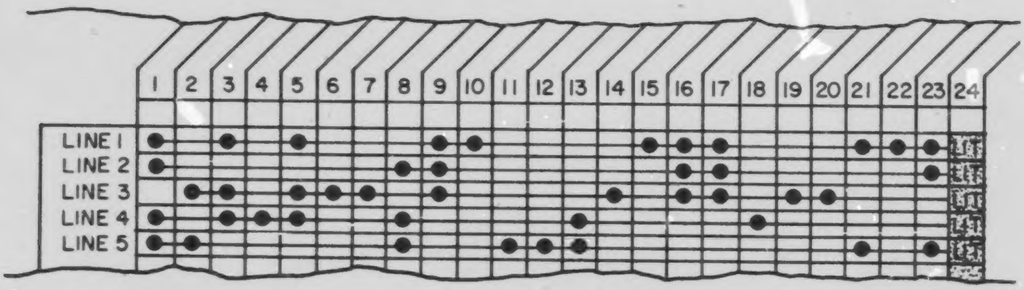
The technique of isolating a fault is based upon a positive approach. It is an analysis of circuitry to verify whether the things that should have happened did happen. The event, if normal, is either readily observable or its signal availability can be measured. If either the action or signal availability is not present, the functional entities, circuit elements, or circuits upon which the event is dependent can be readily ascertained. With other methods of troubleshooting, it was impractical to present all the combinations that could cause a malfunction; for example, a trouble in one of 43 events resulting from parallel actions could represent approximately one trillion possible symptoms. Accordingly, the negative approach to fault isolation or the so-called "symptom-probable cause-remedy method" is totally inadequate for the complexities that often occur in electronic circuits.

Maintenance dependency charts, often more detailed and involved than the samples shown in figure 17-33 A and B, are usually required to represent the complex circuitry of modern


SOURCE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
A

162.160

Figure 17-33A.—Single event line showing dependency marker.



162.161

Figure 17-33B.—Multiple event lines showing parallel and unique functional items.

electronics systems. To help you understand a maintenance dependency chart, the definitions of its key terms and symbols are given below:

EVENT—An action or an availability of a signal at a point in a circuit. The event may be characterized as motor running; temperature normal; lamps lit; lamps out; instruments indicating; signal or voltage available or not available; relay solenoids or thrusters energized, etc.

A solid black rectangle and white lettering represents a front panel indicator or an event recognizable from outside of the cabinetry; an outlined rectangle with black lettering is a circuit point at which a measurement might at sometime be made. This circuit point may not be readily accessible. Internal test points that are readily accessible will be shown as gray-shaded rectangles.

FUNCTIONAL ENTITY—A group of circuit elements that together from a basic functional circuit, such as a filter network, a voltage divider network, an amplifier stage, an oscillator stage, a flip-flop stage, etc.

CIRCUIT ELEMENT—An individual piece part, for which no further breakdown can be made insofar as fault isolation is concerned. Relay or switch contacts, relay coils, resistors, capacitors, motors and fuses are examples, printed circuit boards are not.

The dot (●) represents a circuit element or a functional entity. One aspect or state of circuit or component is represented by (●), and relay contacts are shown by (/●) or (●/) for continuity with relay energized or deenergized, respectively.

DEPENDENCY MARKER—The solid black triangle (▲) is used as a dependency marker. On an event line it denotes that an action or availability of a signal occurring on its line is dependent upon the occurrence of an action or availability of a signal directly above its apex. The signal or action above the dependency marker must be available and within specification for the event on the line of the dependency marker to result, provided that all the circuits and parts symbolically represented along the line are also performing properly.

HOW TO USE THE MAINTENANCE DEPENDENCY CHART

Assume that in the illustration of a signal event line, figure 17-33A, dots (●) represent the basic circuits (oscillator stages, amplifier stages) or circuit elements (relay contacts, relay cards, etc) that provide an action LIT at the end of a circuit chain (event line). The solid triangle (▲) is a dependency marker.

The action LIT depends on the availability of a power source at the A block and on the proper operation of each of the circuits or circuit elements (●) represented along the event line. Now, if the lamp which indicates the action fails to light, any item along the event line, as well as the source A , is a suspect item. Complex interrelated circuits often use some of the same circuits or circuit elements for more than one purpose. Thus, in the case of multiple circuits where many functional items are common to more than one circuit chain (event line) as shown in figure 17-33B, notice that actions (column 24) that occur at the end of these circuit chains are a result of certain

EXPLANATION OF CIRCUIT IDENTIFIER CODES

CATEGORY	DEFINITION
C	Composite circuit (one which is subfunctionalized): composite functional entities containing one or more of the functional entities (L, Q, X, N, M) given in this list are preceded by C.
L	Logic circuits.
Q	Circuits containing one or more nonlinear elements which may be either active or passive: functional entities containing transistors are preceded by Q.
X	Circuits containing one or more nonlinear elements which may be either active or passive: functional entities containing semiconductor diodes are preceded by X.
N	Linear networks: functional entities containing several linear components (resistor, capacitors, etc) arranged in a network or containing a single element used as a network are preceded by N.
M	Circuits containing mechanical devices such as gears, clutches, cams, mechanical stops, etc. are preceded by M.

EQUIPMENT DATA

SUBJECT	PAGE(S)
Symbols/Shading/Logic Devices	3
Foreword	4
Equipment Description	5 - 6
Installation Data	7 - 8
Electrical Connections	7
Post-Installation Procedures	8
Operating Procedures	9 - 10
Weekly Operation Check	10
Preventive Maintenance Procedures	11
Equipment Accuracy Check	11
Operator's Checks and Adjustments	11
Operator Maintenance	11
Calibration/Alignment Procedures	12 - 13
Performance Check Chart	14 - 22
Power Distribution Function	14 - 15
OSS/Heading Function	15 - 16
Velocity/Distance Function	16 - 18
Latitude/Longitude Function	18 - 19
Comparator Card	19 - 20
Component Distance and Ramp Counter Card	20 - 21
Total Distance and Calibration Card	21
Divider Counter Card	21 - 22
Coincidence Card	22

140.176

Figure 17-34.—Functional index and explanation of codes.

common items employed in the parallel generation of the events shown on other circuit lines, and some items that are unique to a single line.

Look again at the multiple event line illustration (fig. 17-33B) for the purpose of analysis. If the lamp does not light on line 4 but does light on lines 1, 2, 3, and 5, it becomes apparent that the circuits or circuit elements represented by the dots in the columns 4 and 18 are the only ones that can be suspected as faulty. All items represented by dots in other columns are proven good because of the proper occurrence of the action LIT on lines 1, 2, 3, and 5.

For each major circuit, consistent with the precise access blocked diagrams and blocked schematics, there is a corresponding maintenance dependency chart. Troubleshooting is accomplished by analyzing the charts. Faults must lie between the first bad event and the last good event. Acetate coverings for maintenance dependency charts may be provided, or the charts plasticized so a grease or carbon pencil can be used for marking out entities which prove good. Marking out all known entities and actions that can be proven good rapidly reveals suspect entities. The use of a pencil to mark out all proven good items is recommended because a technician cannot normally remember all of the entities or dependencies that he has proven good.

INDEXING OF RELATED INFORMATION

Indexing is another important feature of the SIMM. The SIMM method of indexing (fig. 17-34) allows access to any bit of information relative to an assembly in a matter of seconds. The index is organized on the basis of major assemblies and then is broken down to the contained assemblies. Since each of the assemblies is fully treated within a 4- or 6-page data package, and the organization of details is always consistent, access to the desired kind of detail is almost immediate. The maintenance dependency chart is used to identify the functional entity or circuit element that is suspected, the assembly in which it is contained, and the cabinet containing the assembly. Accordingly, in using the index you need only find the cabinet nomenclature and look to the page number for the contained assembly data package.

ALIGNMENT PROCEDURES

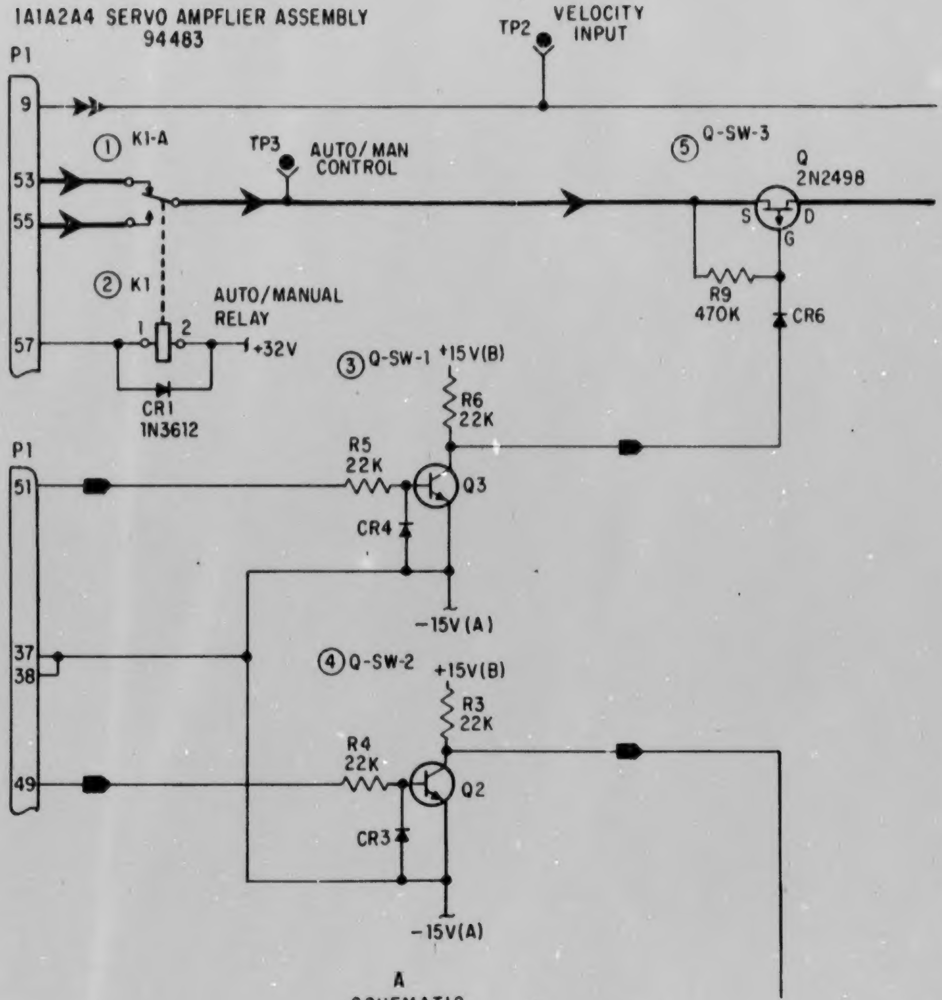
Alignment procedures for each functional section of the set or system, as necessary, are included on as few pages as possible. The method of identifying alignment procedures is the same as for making other identifications from the maintenance dependency chart. The alignment procedures are directly keyed from the signal specifications listed on the maintenance dependency chart. If a particular event shown on the dependency chart is below specification and correctable by alignment, the step in the alignment chart is easy to find. Each part of the maintenance dependency chart treats a major functional segment of equipment. Likewise, the alignment actions are organized (charted) for each major functional segment of the equipment. The identification system for the charts is used for the alignment procedure chart. For example, alignments that affect events on maintenance dependency chart, part 2, will be found on alignment chart, part 2, etc. When required, alignment of subassemblies outside of the set environment will be contained along with the other details of individual assemblies in the data package for the assembly.

PARTS LOCATION AND IDENTIFICATION

Equipment and assembly half-tone and line drawings are overlayed with a blue-colored grid on which coordinates are placed to assist in parts location. Associated with the parts-location illustration is a cross-reference table identifying the items by reference designations, their coordinate positions, and significant military-type numbers or manufacturers' part numbers.

REPAIR OF MECHANICAL ASSEMBLY

Mechanical assemblies, gear trains, etc are illustrated to the extent necessary to assure sufficient data for repair. When assemblies are illustrated in exploded form, index numbers are cross-referenced to contractors' drawing numbers or to contractors' vendor's part numbers. Subassemblies, such as synchro motors, that frequently are identified by nonreadily translatable MIL-type numbers also include sufficient meaningful data for ordering purposes. When complex assembly and disassembly procedures are involved but not obvious, detailed procedures


1A1A2A4 SERVO AMPFLIER ASSEMBLY
94483
P1
9
53
55
57
① K1-A
② K1
AUTO/MANUAL
RELAY
1
2
+32V
CR1
1N3612
TP3
AUTO/MAN
CONTROL
TP2
VELOCITY
INPUT
⑤ Q-SW-3
Q
2N2498
S
D
G
R9
470K
CR6
③ Q-SW-1
+15V(B)
R6
22K
R5
22K
Q3
CR4
-15V(A)
P1
51
37
38
49
④ Q-SW-2
+15V(B)
R3
22K
R4
22K
Q2
CR3
-15V(A)

A
SCHEMATIC

1A1A2A4 SERVO AMPLIFIER ASSEMBLY

COMPARES EITHER THE ANALOG DEPTH SIGNAL OR THE MANUAL DEPTH SIGNAL WITH THE ERROR VOLTAGE FEEDBACK. IF THERE IS ANY DIFFERENCE BETWEEN THESE TWO SIGNALS, A DIFFERENCE SIGNAL IS GENERATED, AMPLIFIED AND USED TO DRIVE THE SERVO MOTOR.

① K1A1-A

ENERGIZED: CONNECTS ANALOG DEPTH SIGNAL TO Q-SW-3. DE-ENERGIZED: CONNECTS MANUAL DEPTH SIGNAL TO O-SW-3.

② K1

ENERGIZED WHEN THE MANUAL MODE IS SELECTED.

③ Q-SW-1 SWITCH

CONDUCTS FOR ONE HALF CYCLE OF THE INPUT CHOPPER REFERENCE. TURNED ON AND OFF AT A 400HZ RATE. CR4 PROTECTS Q3 FROM EXCESSIVE BASE TO EMITTER REVERSE VOLTAGE. CONDDCTION IS 180° OUT OF PHASE WITH CONDUCTION OF Q-SW-2. WHEN Q-SW-1 IS CUT OFF +15 VOLTS IS APPLIED TO THE GATE OF Q4, CUTTING OFF Q-SW-3.

④ Q-SW-2 SWITCH

OPERATION IDENTICAL TO Q-SW-1 EXCEPT CONDUCTS ON THE ALTERNATE HALF CYCLE OF THE CHOPPER REFERENCE.

⑤ Q-SW-3 SWITCH

TURNED ON AND OFF AT A 400HZ RATE BY THE OUTPUT OF Q-SW-1. SINCE POSITIVE VOLTAGE AT THE GATE WILL CUT OFF Q-SW-3, Q-SW-1 WILL BE TURNED ON AND OFF AT A 400HZ RATE. THUS, THE DEPTH VOLTAGE IS APPLIED TO C3 AT A 400HZ RATE.

B
TEXT

140.177

Figure 17-35.—SIMM keyed-text.

are given. Exploded views on the same or facing pages will describe and illustrate these procedures.

IMPROVEMENTS

Compared to the already described SIMM, newer editions of the manual will show improvements in method of presentation, use of MDC, and size.

Instead of the blocked text, the improved manuals use a keyed text method of presentation in which the text material is arranged in tabular format and keyed to the diagram by circled numbers as shown by figure 17-35. This method permits significantly more text material to be presented than the blocked text method. Besides being used with the schematic diagrams, the keyed text is also used with the precise access block diagrams (called functional block diagrams), and the overall block diagram (called the function description diagram).

Instead of only one MDC for each major function, newer manuals will have additional MDCs for the functional block and schematic diagrams. The MDCs will also be provided with an acetate or Mylar overlay so that the troubleshooter can use a grease pencil to mark his progress. The size of the new SIMM will be 11 by 27 inches, instead of 15 by 35 inches. This new size gives it a folded dimension of 9 by 11 inches the same size as conventional manuals.

CHAPTER 18

NEW INSTALLATIONS EQUIPMENT

New equipments are installed continually on Navy ships. Some are modifications of equipments that have been in use, whereas other equipments are completely new. Basic descriptions of new equipments are given here to help the IC Electrician perform the maintenance they will require.

INTERIOR VOICE COMMUNICATIONS SYSTEM

Voice communications systems are the nerve system of a naval ship. The effectiveness and efficiency of communications is of prime importance in all shipboard evolutions. There is a continuous flow of information and data which form the basis for every decision and command at every level of command. The combat effectiveness of every ship in the fleet is affected by the readiness and quality of its interior communications systems.

Developed in the 1930's, the current systems consist mainly of independent or individual circuits. These circuits can be classified into four basic communications links or minor variations of them:

- Sound-powered telephones
- Intercommunication units (intercoms)
- Dial telephones
- General announcing systems

They are provided in three basic modes: person-to-person (point-to-point), common talking and listening (conference), and announcing (broadcast). Depending on the individual shipboard evolution to be supported, the most applicable technique and mode of communication is provided. The major physical characteristic of a current system is, except for the limited dial telephone, that each individual circuit is wired between a certain space and the person who is to be served by that circuit. Such a shipboard communications system is both conservative and reliable; its primary requirement is reliability.

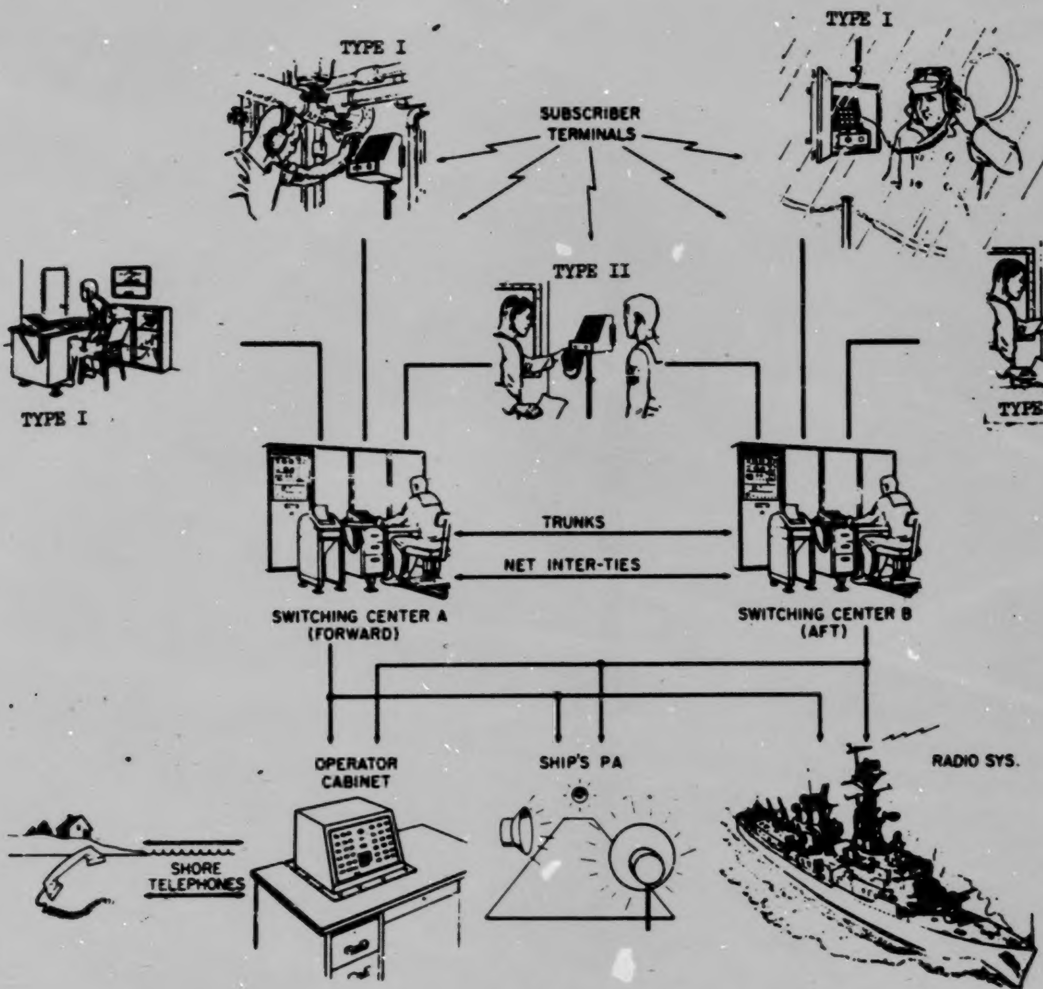
Individual circuits, however, have severe limitations. They are hard wired and inflexible, whereas a ship's requirements are always changing. Designed three to five years before the ship hits the water, a system of individual circuits is inadequate from the ship's first day at sea, and never catches up. It is not possible for such a system to handle efficiently all the command communications.

The Interior Voice Communications System (IVCS) meets the reliability requirements of the old voice communications systems and is flexible to an extent never achieved with the old systems. Though IVCS provides the same basic modes of communications (broadcast, point-to-point, and common talking) it is a single integrated system. By design, the lines or terminations are identical and cables from the switching centers are identical, no matter what function they serve. The communications requirements of each station are basically established by the type of station equipment and the programming of the control equipment. The station equipment continues to function as an intercom, a telephone, a jackbox, or whatever combination is required, but the basic form for all terminals or stations is identical.

BLOCK DIAGRAM AND DESCRIPTION

Figure 18-1 is a diagram of the IVCS. The shipboard system consists of two identical switching centers (one forward, one aft) each serving a number of subscriber terminals throughout the ship; trunks connecting the centers together; and interface units to extend the voice transmission to external systems.

Each of the subscriber terminals is connected to at least one of the switching centers.


TYPE I
SUBSCRIBER TERMINALS
TYPE I
TYPE II
TYPE I
TYPE III
TRUNKS
NET INTER-TIES
SWITCHING CENTER A (FORWARD)
SWITCHING CENTER B (AFT)
OPERATOR CABINET
SHIP'S PA
RADIO SYS.
SHORE TELEPHONES

140.178

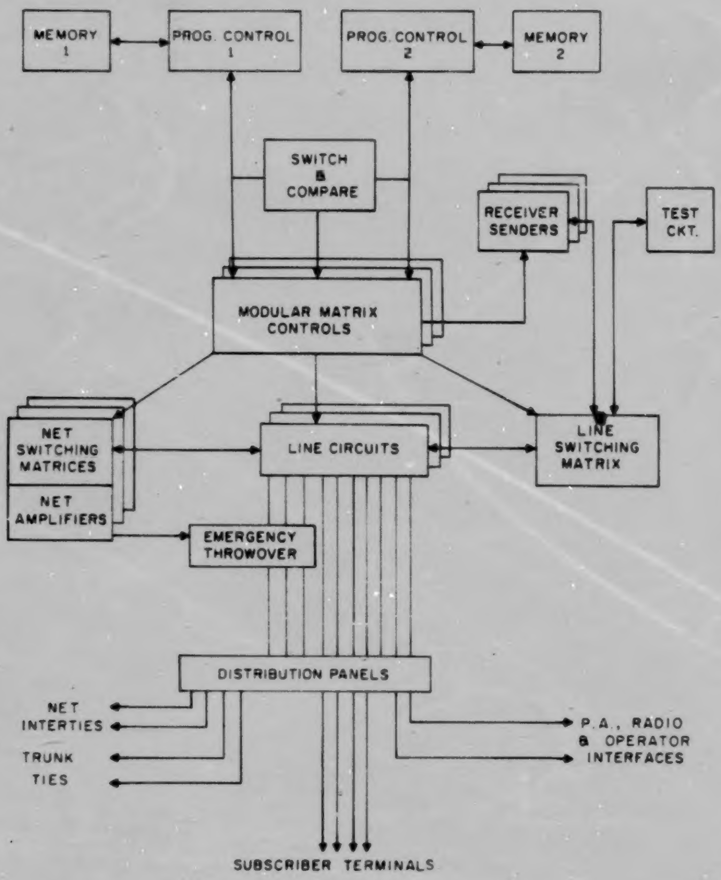
Figure 18-1.—Advanced Interior Communications System.

The switching centers connect subscriber terminals to each other, to nets, to the interface units, or to trunks to reach subscribers serviced by the other center.

The interface units permit the subscriber terminal to be connected to the ship's PA system, to the ship's radio system, and to an operator's cabinet. By virtue of the connection to the operator's cabinet, a call may be extended to any shore telephone system to which the operator has access.

The electronic switching system is basically a conventional electronic exchange having a number of relatively conventional variations.

From a functional standpoint, the electronic switching center incorporates a number of operational features which are available in most communication switching centers but in a more useful form than in the conventional electromechanical switches. For example, the IVCS provides add-on conferences that can be set up as required; the hunt not-busy line between any


MEMORY 1
PROG. CONTROL 1
PROG. CONTROL 2
MEMORY 2
SWITCH & COMPARE
RECEIVER SENDERS
TEST CKT.
MODULAR MATRIX CONTROLS
NET SWITCHING MATRICES
NET AMPLIFIERS
LINE CIRCUITS
LINE SWITCHING MATRIX
EMERGENCY THROWOVER
DISTRIBUTION PANELS
NET INTERTIES
TRUNK TIES
P.A., RADIO & OPERATOR INTERFACES
SUBSCRIBER TERMINALS

140.179

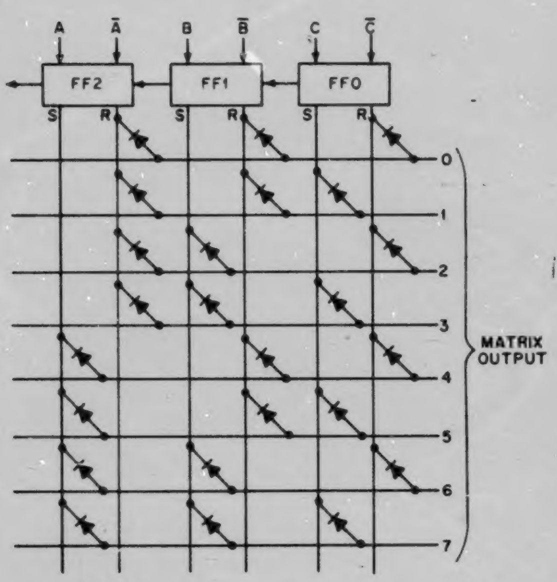
Figure 18-2.—Interior Communications Switching Center block diagram.

two or more nonconsecutive lines and call forwarding. In addition override can be assigned to any line (or withheld from any line). A number of areas of restriction can also be assigned and, through processor programming, selective access to any given line within the exchange can be made available.

Figure 18-2 is a functional block diagram of the interior communications switching center (ICSC). The ICSC consists of a central, fully duplicated, common control directing the interconnection of subscriber lines through a 4-stage line switching matrix or a 1-stage net switching matrix. A matrix is defined as a rectangular array of intersections of input-output leads, with diodes, relays, magnetic cores, or other circuit elements connecting at some intersections.

A simplified diagram of a diode decoder matrix is shown in figure 18-3.

The program control unit (PCU) performs all of the steps necessary to process a call. It directs the operation of the line and net matrices through the matrix control unit; exchanges data with the receiver-senders to process the dual tone multi-frequency (DTMF) signaling; and performs all of the data conversions and bookkeeping required to accomplish the switching task. Two PCU's are provided and an automatic switchover unit which determines which unit is on line. Each program control provides permanent storage of



124.53

Figure 18-3.—Diode decoder matrix.

control routines and translation and restriction tables, and temporary storage of the current status of all subscriber terminals and switching matrix paths in its memory. The receiver-senders provide the analog-to-digital conversion necessary to change the multi-frequency signaling tones into binary data patterns suitable for manipulation and storage by program control. The receiver-senders also perform digital-to-analog conversion for trunk outpulsing and the transmission of supervisory tones such as ring, busy, dial tone, and so on.

The matrix control unit routes the commands from program control to the line circuits and switching matrices. Matrix control is essentially a decoding system which permits a few interface signals from program control to make or break any one of the thousands of possible connections in the matrices. The line circuits provide the terminal's transmission path connections to the switching matrices, the control logic for the supervision signals between the terminals and the ICSC, and decode logic to assist matrix control in routing the connect-disconnect signals into the matrices. The line switching matrix contains the crosspoints to interconnect any subscriber to any other subscriber, receiver-sender, interswitch trunk, or interface unit.

The activation and release of the crosspoints is under the direction of matrix control with some of the signals routed through the line circuits.

The net switching matrix contains the crosspoints to connect selected subscribers to particular net amplifiers in such a manner as to permit a conference conversation between all subscribers connected to the same net amplifier. The selection, as to which subscriber lines will have access to which nets, is determined by a combination of fixed wiring and a cross-connecting field which is completed at installation in combination with a net access table in memory accessing up to 120 nets. The net matrix relays are dedicated; that is, each relay is used to connect one subscriber to one net only. The activation and release of the relays is under the direction of matrix control and the line circuits. The emergency switchover equipment provides the relays to transfer selected subscribers to the interswitch trunks and net inter-ties for service by the remote switching center in the event of a total switching center outage.

The main distribution panel provides the tie-points for terminating the ship's cables. Maintenance equipment provides means for program control to test itself as well as the other functional blocks. Both automatic and manually controlled tests are provided.

PROGRAM CONTROL

Program control controls the operation of the entire switching center. The other functional subsystems provide program control with data on request and execute the commands generated by it. Program control performs all of the data manipulation, storage, and logical decisions necessary to convert supervision and signaling data into switching-path connections. It interfaces and controls the receiver-senders, matrix control, and maintenance operations.

Receiver-Sender Interface

The receiver provides program control with a binary presentation of the multifrequency signaling transmitted by the subscriber terminal. The receiver has no data storage facility. Program control interrogates each busy receiver at 20-ms intervals to assure that no signaling information is lost, performs validity checks on dialed digits, and assembles the dialed number in the memory. The sender transmits supervisory tones or out-pulse signaling on command by program control.

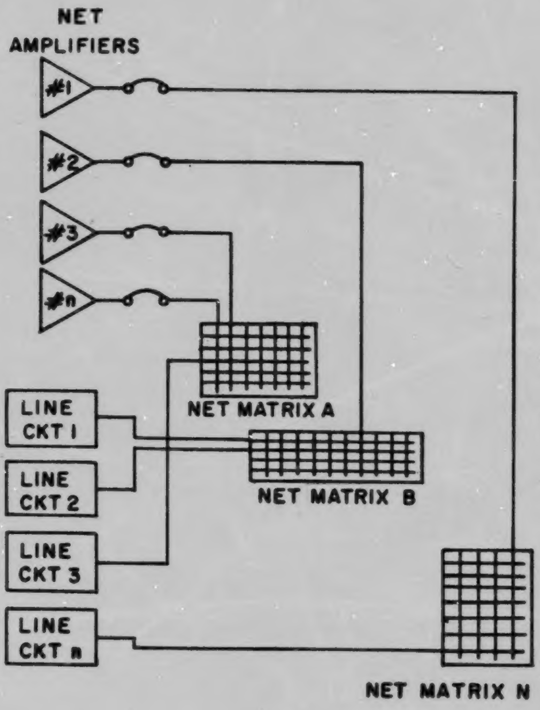
Matrix Control Interface

Program control works through matrix control to activate and release switching matrix connections, to activate and de-activate subscriber terminals to achieve hands-free operation, and to detect-release requests from subscribers.

The interface to matrix control identifies the calling and called terminal location in the matrix, the link number (switching matrix path), and the change to be made, that is, make or break the connection. Matrix control decodes the data so that only the crosspoints and terminals identified are activated or deactivated. Program control may withhold some data in order to affect only part of a connection; this is necessary, for example, to release an over-ride caller without disturbing the original connection. When program control scans terminal service-release requests, matrix control responds to each line identified with the current status of its supervision signal. Program control then compares this status with the previous status stored in memory to determine if any change has occurred and acts accordingly.

Maintenance Interface

Associated with the control rack are a maintenance panel, tape reader, printer, and test circuit. Program control interfaces with these devices in order to receive requests for special maintenance routines, to execute maintenance routines, and to display and print out the results.



140.180

Figure 18-4.—Net access matrices.

LINE AND NET MATRICES

The major matrices, both line and net, are comprised of four-pole miniature reed relays operated from a single coil. A solid-state device energizes the relay coil. The holding current is thus independent of the shock or vibration.

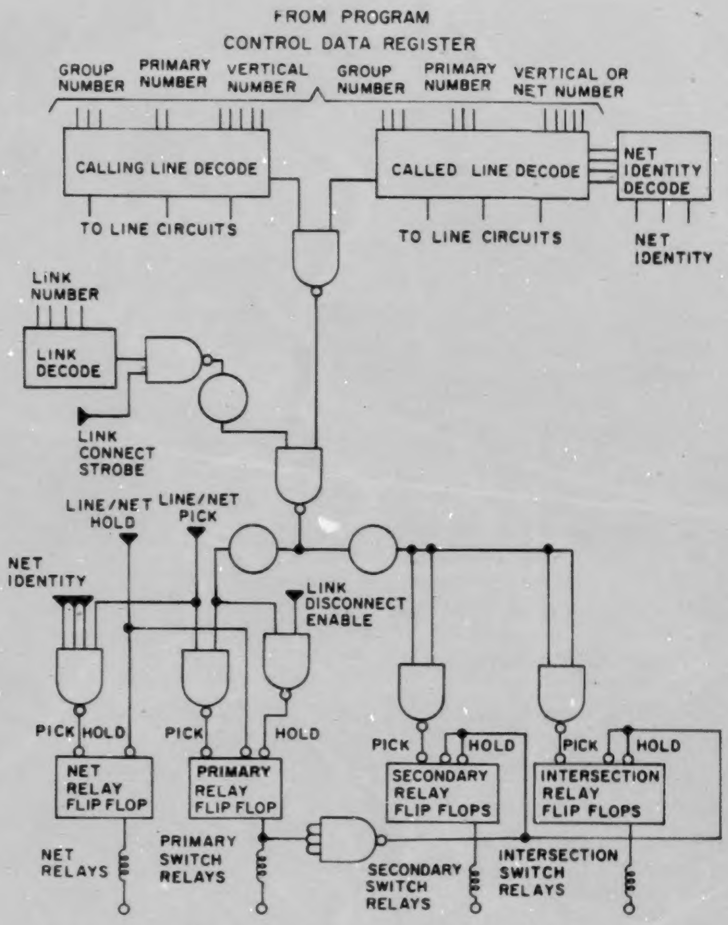
The line matrix is constructed as a 4-stage switching network. Based on traffic and modular packaging considerations, the switch configuration provides for a modular approach to equipping various sizes of systems.

The net matrix is comprised of a group of rectangular matrices some of which are provided to designated lines and nets. A group of small matrices is wired to cross connection fields where additional lines may be connected to the inputs, and outputs may be connected to any of the available nets. Only those terminals which are patched via net access relays to a net may dial that particular net. Figure 18-4 shows the net matrices.

MATRIX CONTROL

Matrix control provides the decoding and driver buffers to control all of the switching matrices. Figure 18-5 is a simplified block diagram of the matrix control logic. Program control provides all the data necessary to establish or release a connection in the form of a calling and called equipment location and a link number. For net calls, the net identity replaces the called equipment location and the link number is not used.

The called equipment location is in the form of a 3-bit group number, a 3-bit primary switch number, and a 5-bit vertical number. The calling line decode (see fig. 18-5) reduces this 11-bit


FROM PROGRAM
CONTROL DATA REGISTER
GROUP NUMBER
PRIMARY NUMBER
VERTICAL NUMBER
GROUP NUMBER
PRIMARY NUMBER
VERTICAL OR NET NUMBER
CALLING LINE DECODE
CALLED LINE DECODE
NET IDENTITY DECODE
TO LINE CIRCUITS
TO LINE CIRCUITS
NET IDENTITY
LINK NUMBER
LINK DECODE
LINK CONNECT STROBE
LINE/NET HOLD
LINE/NET PICK
NET IDENTITY
LINK DISCONNECT ENABLE
PICK
HOLD
PICK
HOLD
PICK
HOLD
PICK
HOLD
NET RELAY FLIP FLOP
PRIMARY RELAY FLIP FLOP
SECONDARY RELAY FLIP FLOPS
INTERSECTION RELAY FLIP FLOPS
NET RELAYS
PRIMARY SWITCH RELAYS
SECONDARY SWITCH RELAYS
INTERSECTION SWITCH RELAYS

140.181

Figure 18-5.—ICS matrix control block diagram.

data into a 3-bit code which is distributed to all the line circuits. The three bits are then decoded in the line circuits so that only one line circuit out of the total ICSC is enabled by the equipment location.

The called equipment locations is handled by the same means. The net identity decode is an adjunct to the called line decode since both are never on the same call. For matrix control to determine whether the called equipment location is a line or not, a dummy primary switch code is used to identify nets.

The link code, used only in line matrix switching, determine the switching matrix path. After decoding the link number, matrix control AND's this signal with the primary switch number decode from the calling and called decode networks (represented in the figure by the OR gate between the two). Thus, when these signals reach the matrix, they have been decoded to the level of particular links on specific primary switches.

Every relay in the line and net matrix is controlled by the flip-flop. The flip-flops are set by a "pick" decode gate and are reset when a "hold" signal ends. In the line matrix, two hold signals are used and the absence of either one resets the flip-flop and releases the delay.

Each line circuit sends a "PICK" signal up to the matrix. This occurs only when the line decodes its own identity from the calling or called decode outputs and a strobe is present. (The strobe is not shown in figure 18-5.)

To set a net connection, the calling line equipment location is decoded through the calling line decode network to generate the "line/net pick" signal. The net identity provides the other inputs so that one, and only one, net relay flip-flop is set.

To establish a line matrix connection, two primary switch relays and one secondary switch relay must be set. The calling and called line decode networks define two lines which provide two "line/net pick" signals; one for each of the primary switch relays to be set. The other input for the primary switch pick gates is provided by the link decode.

The link decode also provides both pick signals for the secondary switch pick gates. Two signals come from the link decode—one defining the calling primary and the other defining the called primary—each combined with the link number to differentiate the several secondaries which can be used to interconnect the primaries. These two signals are common to only one secondary or intersection switch pick gate and this relay is set.

The "link/net hold" signal from the line circuit begins when the line circuit is first strobed to generate the pick signal and set the connection. The "hold" signal remains until a disconnect is effected by again placing the lines equipment location in the calling or called decode network and generating a reset strobe. When the hold signal is reset, the terminal power returns to standby.

There are circumstances when a call cannot be relaxed in the normal manner, such as when a receiver-sender is released after ring tone or an over-ride connection is to be released without disturbing the original connection. In these two cases, one of the line hold signals is holding two primary switch relays and only one is to be released. For this purpose, the second hold signal for primary relays is used.

The "link disconnect enable" signal (see fig. 18-5) has a polarity such that the second hold signal is normally present. When activated, this signal inhibits the hold signal for a particular link on a particular primary switch as defined by the link decode gating.

REDUNDANCE AND SWITCHOVER CONTROL

To provide satisfactory communication, the switching center must provide continuous service to its subscribers. This goal has been pursued in the matrix design by using modularity and redundancy and in the program control design by using tandem operation with automatic switchover.

To achieve modularity in matrix control, each 103-terminal group contains its own matrix control section. Each controls the terminals and that portion of the switching matrices associated with the group. A malfunction within any section of matrix control will, therefore, only affect one terminal, or a small group of terminals, or the grade of service for the group. Total service loss is not possible since each section controls only a portion of the total matrix. The detection of failures in receiver-senders and individual portions of the line and net matrices is done by program control through he use of periodic maintenance routines. Should a receiver-sender or matrix module become faulty, it is removed from service until repaired.

The common control area, however, contains circuitry which is required for all traffic processing. Component failure in this area could cause catastrophic failure of the switching center. For this reason, complete redundance is utilized in program control. Failures in program control are detected by:

- Parity, checking.
- Self-test (diagnostics).
- Program traps.
- Time-outs.
- Simultaneous processing and comparison of the outputs of the two PCU's.

This arrangement of simultaneous operation eliminates the problem of providing the standby unit with current call data when switchover is required. Since the standby unit is processing all traffic, its memory unit is always up to date. (Special consideration for "catching up" after repair of a fault is provided.)

The redundant program control processes all traffic along with the on-line unit. At key intervals, the routine halts while a comparator checks the two outputs for identity. These halts also serve to synchronize the two units which operate from independent master clocks.

As soon as both program control units reach the comparison point, the comparator checks the outputs and signals back the results to both units. If the outputs are the same, the program controls continue their normal traffic processing routines; if not, a check is made by switchover control to see if any auxiliary indication is present to determine timeouts. If no such indication is present, the program control units are diverted to a self-test routine.

The unit which does not successfully complete the self-test is taken off-line by the switchover control logic. Any time the comparator detects a fault, an alarm indication is given and a complete description of the call in progress at the time is printed out. The comparison logic is then disabled so that the same fault will not continuously halt the traffic processing. This disable condition is reset from the maintenance console when the fault is cleared.

POWER SYSTEM

The power system consists of two sets of battery chargers which are fed from the ship power system. These battery chargers serve the dual function of system power supplies and battery chargers. During normal operation, the system power needs are provided by the two sets of battery chargers which are paralleled with a 6-volt and a 24-volt battery. Under normal conditions, these bateries are continuously trickle-charged by the battery chargers. In the event of a ship power interruption, the batteries immediately supply the necessary power for full operation up to a four-hour period. Upon the reestablishment of ship power to the system, the battery chargers automatically resume supplying system power and recharge the batteries without disturbing system operation. Chargers are duplicated for each voltage.

D-C to a-c converters are fed from the 24-volt d-c power bus and provide a-c power for the memory power supplies and system fans. Since the inverters are fed from this bus, they are unaffected by the interruption of ship power.

The ICS terminal units are of three general types. Type I units terminate single lines of the system and are subdivided into eight forms. Type II units terminate two lines of the system, one from each ICSC, and are subdivided into four forms. Type III terminals have calling capability only to one predetermined net and are supplied in one form.

CONTROL PROGRAM

The main control loop (see fig. 18-6) directs the operation of program control through the various routines and sub-routines required to process a call. The loop is divided into the three major sub-sections of call processing, line scanning, and test and service. There is also an interrupt state for those functions which are dependent on real-time processing.

Call processing includes all routines required to process a call when dialing has been completed. It results in the setup of line-to-line or line-to-net connections, the sending of supervisory tones, the release of receiver-senders when they are no longer required, and the internal record-keeping associated with call forwarding.

Test and service includes those routines associated with automated self-test by the switching center, plus maintenance services such as taking lines or common equipment out-of-service and returning them to service.

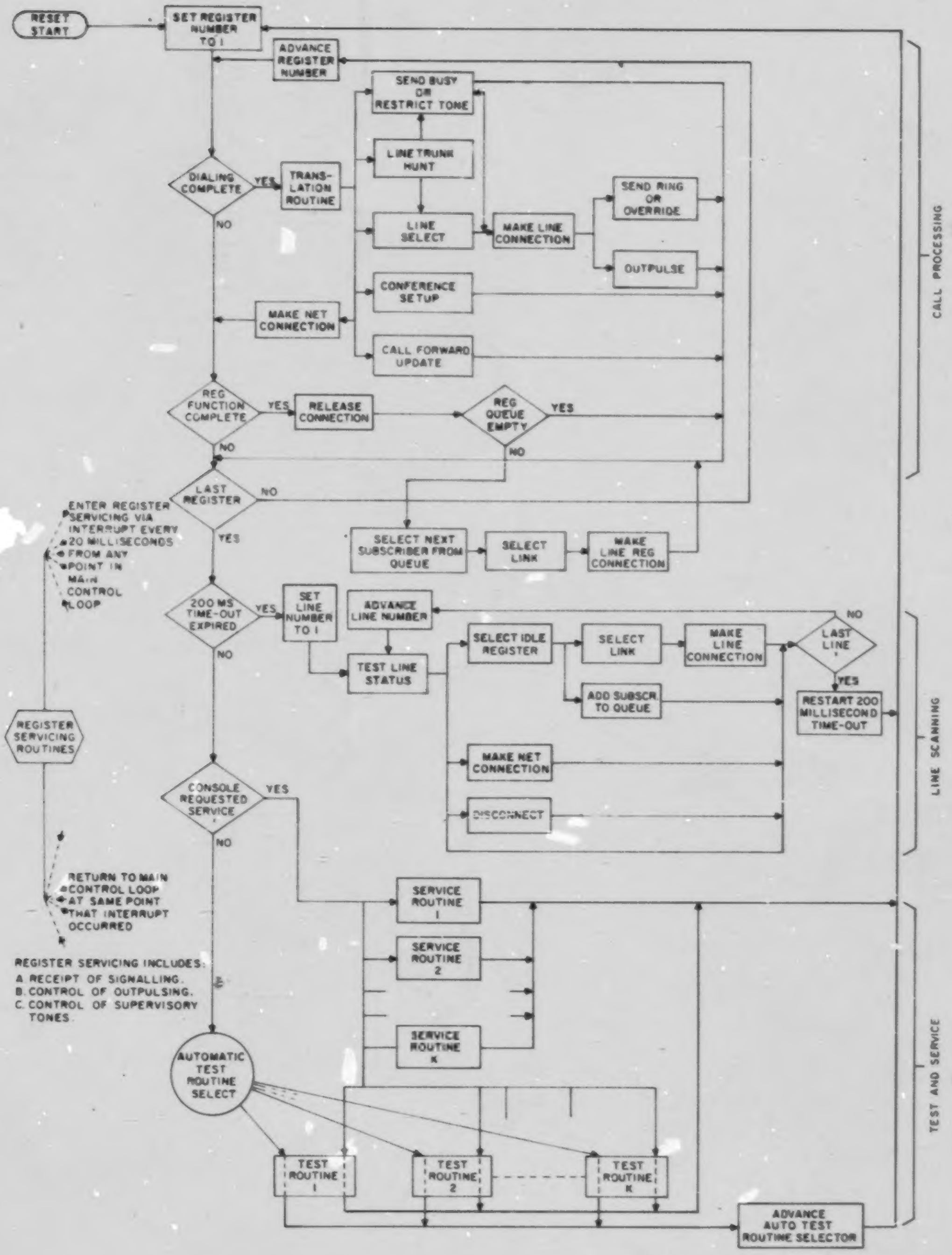
The interrupt state includes those routines which receive dial digits from the register and store them in memory and transfer dial digits from memory to the senders for outpulsing.

The main control loop also serves to allocate the time spent by program control in each aspect of traffic processing. Call processing is given first priority on any pass through the control loop. Program control will remain in the call processing section until all receiver-senders which have received complete dialing or completed their functions are processed.

Line scanning is given next priority, but only if at least 200 ms has elapsed since the last pass through the line scan routines. The 200 ms timer is restarted at the conclusion of the line scan as program control returns to the call processing section to determine if any new calls have reached this point during the time spent in line scanning.

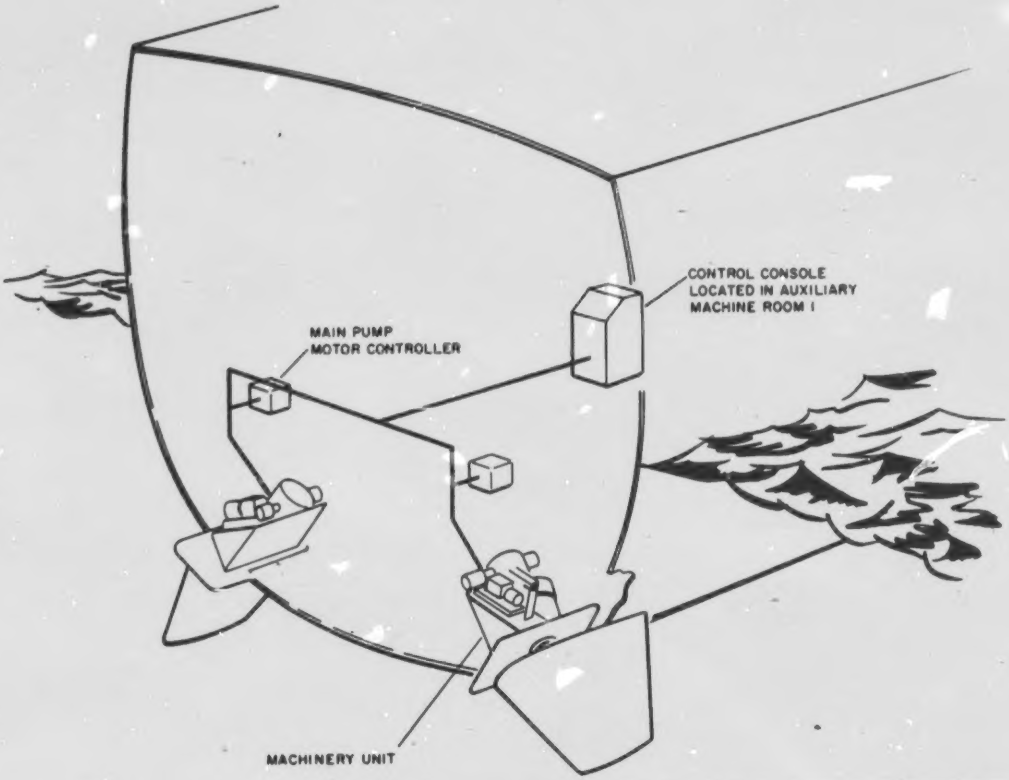
When call processing has been completed, and line scanning has been performed within the last 200 ms, the control loop proceeds to test and service routines. If a particular routine has been requested by maintenance personnel via the console, that routine will be performed. Otherwise, one of the self-tests will be automatically selected and performed. When completed, the selector will be advanced so that the next pass will select another test.

It should be emphasized that during periods of heavy traffic program control will spend more time in the call processing and line scanning sections of the loop and correspondingly


RESET START
SET REGISTER NUMBER TO 1
ADVANCE REGISTER NUMBER
SEND BUSY OR RESTRICT TONE
LINE TRUNK HUNT
DIALING COMPLETE
YES
TRANS-LATION ROUTINE
SEND RING OR OVERRIDE
LINE SELECT
MAKE LINE CONNECTION
NO
OUTPULSE
CONFERENCE SETUP
MAKE NET CONNECTION
CALL FORWARD UPDATE
REG FUNCTION COMPLETE
YES
RELEASE CONNECTION
REG QUEUE EMPTY
YES
NO
NO
LAST REGISTER
NO
ENTER REGISTER SERVICING VIA INTERRUPT EVERY 20 MILLISECONDS FROM ANY POINT IN MAIN CONTROL LOOP
YES
SELECT NEXT SUBSCRIBER FROM QUEUE
SELECT LINK
MAKE LINE REG CONNECTION
200 MS TIME-OUT EXPIRED
YES
SET LINE NUMBER TO 1
ADVANCE LINE NUMBER
NO
SELECT IDLE REGISTER
SELECT LINK
MAKE LINE CONNECTION
LAST LINE
NO
TEST LINE STATUS
YES
ADD SUBSCR. TO QUEUE
RESTART 200 MILLISECOND TIME-OUT
REGISTER SERVICING ROUTINES
MAKE NET CONNECTION
CONSOLE REQUESTED SERVICE
YES
DISCONNECT
NO
RETURN TO MAIN CONTROL LOOP AT SAME POINT THAT INTERRUPT OCCURRED
SERVICE ROUTINE 1
SERVICE ROUTINE 2
REGISTER SERVICING INCLUDES:
A. RECEIPT OF SIGNALLING.
B. CONTROL OF OUTPULSING.
C. CONTROL OF SUPERVISORY TONES.
SERVICE ROUTINE K
AUTOMATIC TEST ROUTINE SELECT
TEST ROUTINE 1
TEST ROUTINE 2
TEST ROUTINE K
ADVANCE AUTO TEST ROUTINE SELECTOR
CALL PROCESSING
LINE SCANNING
TEST AND SERVICE

140.182

Figure 18-6.—Main control look flow chart.



140.183

Figure 18-7.—Typical fin stabilizer installation.

less time in test and service. During low traffic periods, most of the time will be spent performing tests. The control loop automatically reallocates program control's time to suit the current traffic needs.

An 8,192-word memory is required to perform the ICSC switching function for a maximum 600 line system. The memory is divided into approximately 1,024 words for temporary working storage relating to current call processing, 3,072 words for semipermanent storage for fixed translation tables, and the remaining 4,096 words for the control program.

FIN STABILIZER SYSTEMS

The fin stabilizer systems installed on ocean escort class ships provide a stable weapons platform in heavy seas or during high speed maneuvers. The systems being installed on DEs and DEGs are active, which means that some form of energy is supplied to move the fins. Though they are manufactured by different companies, only the system designed by Sperry Rand will be described here since it is considered a representative system. This system provides a high degree of ship safety and permits all-weather operation.

GENERAL DESCRIPTION

The main components of the ship stabilizing system are two machinery units, a control console, and two motor controllers, whose approximate locations aboard ship are given by figure 18-7.

Each machinery unit consists of a fin and fin-actuating machinery. This equipment is designed to be welded to the ship's hull.

Two main hydraulic pump units are shock mounted on the forward sides of the machinery units. Each pump unit consists of a variable delivery pump, a 50-hp electric drive motor, and accessories.

All roll measuring devices and equipment for computing the required stabilizing actions are housed within the deck-mounted control console. Its front sloping panel contains the controls and indicators for monitoring the fin stabilizer operation.

PRINCIPLES OF OPERATION

Wave action, which causes the ship to roll, can be counteracted by applying righting or stabilizing moments to the ship in the direction opposite the direction of the disturbing wave action. One method of producing those moments is by means of two underwater fins. The capacity of these fins to stabilize a ship depends upon the speed of the vessel, size of the fins, and the manner in which they are controlled.

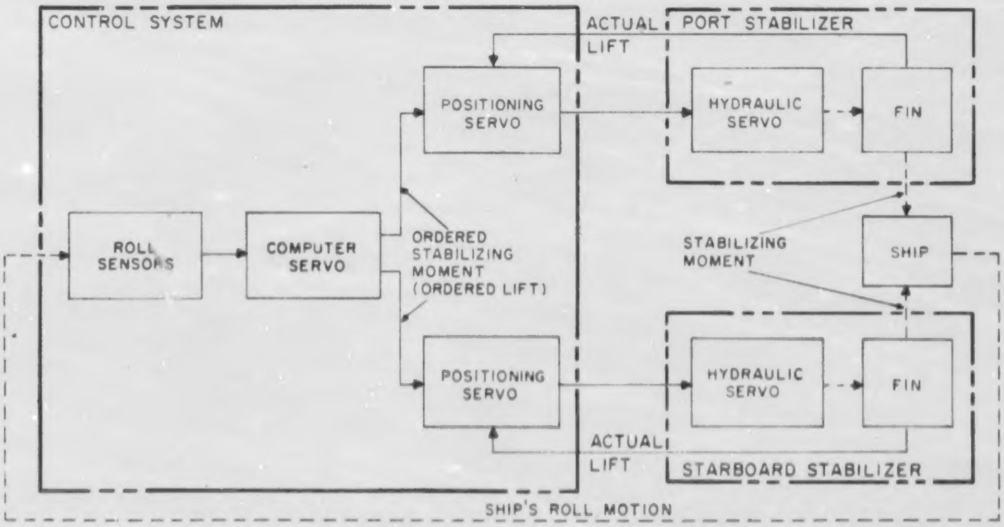
Stabilization System

The stabilization system contains the control system (fig. 18-8) which computes and orders the proper stabilizing moment, and the machinery units which develop the ordered stabilizing moment.

Roll sensors measure the disturbing action applied to the ship by measuring the ship's roll response to it; they then supply data to develop the required stabilizing moments. The computer servo unit orders the fin servo to tilt the fin, creating a fin lift or force. A stabilizing moment (or antiroll torque) results from the action of this force on the lever arm between the fins and the ship's center of roll.

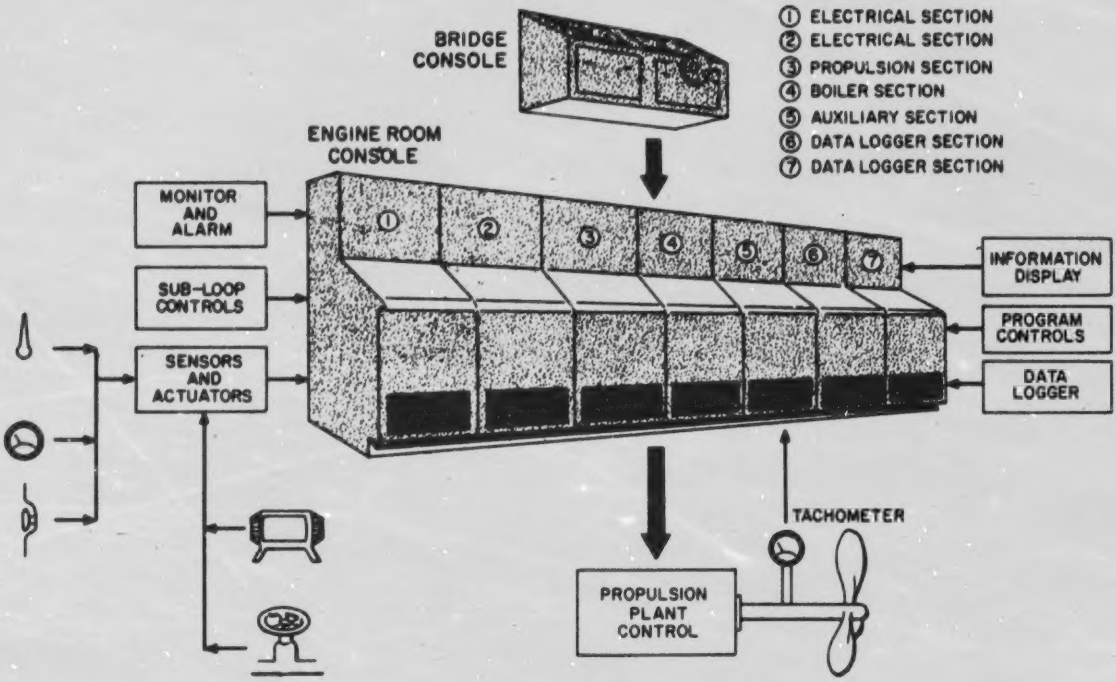
Although each fin responds independently to ordered stabilizing signals, both cooperate to produce equal forces but in opposite directions. The equality in fin forces or lifts is assured by equality of the ordered lift signals and by measurement of the actual lift exerted by each fin. The ordered lift signal and the actual lift signal are compared; any difference in them is used to change the fin angle until actual lift is equal to ordered lift.

CONTROL FUNCTIONS.—The fin stabilizer system senses roll velocity and roll angle, both of which are measured as electrical signals and used to compute the corrective force required. Roll velocity, the primary control signal, is measured directly by a spring-restrained rate gyro. Dynamic roll angle is an input from the ship's vertical reference (gyrocompass) to a fixed rotor control transformer. The static roll


CONTROL SYSTEM
ACTUAL LIFT
PORT STABILIZER
POSITIONING SERVO
HYDRAULIC SERVO
FIN
ROLL SENSORS
COMPUTER SERVO
ORDERED STABILIZING MOMENT (ORDERED LIFT)
STABILIZING MOMENT
SHIP
POSITIONING SERVO
HYDRAULIC SERVO
FIN
ACTUAL LIFT
STARBOARD STABILIZER
SHIP'S ROLL MOTION

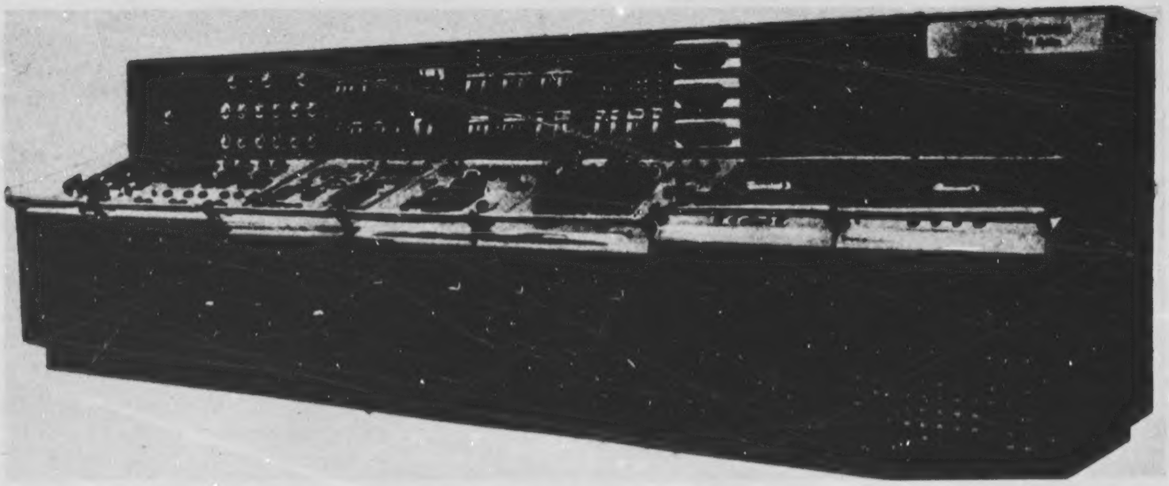
140.184

Figure 18-8.—Block diagram of fin stabilizer system.


BRIDGE CONSOLE
① ELECTRICAL SECTION
② ELECTRICAL SECTION
③ PROPULSION SECTION
④ BOILER SECTION
⑤ AUXILIARY SECTION
⑥ DATA LOGGER SECTION
⑦ DATA LOGGER SECTION
ENGINE ROOM CONSOLE
MONITOR AND ALARM
SUB-LOOP CONTROLS
SENSORS AND ACTUATORS
INFORMATION DISPLAY
PROGRAM CONTROLS
DATA LOGGER
TACHOMETER
PROPULSION PLANT CONTROL
①
②
③
④
⑤
⑥
⑦

27.344

Figure 18-9.—Central operations system major units.



27.345

Figure 18-10.—Engineroom console.

or list angle is measured by a heavily damped linear accelerometer. The signals are summed in an amplifier and fed to the computer servo which produces the ordered lift signal. Limit stops in the servo prevent ordering a lift in excess of fin capacity.

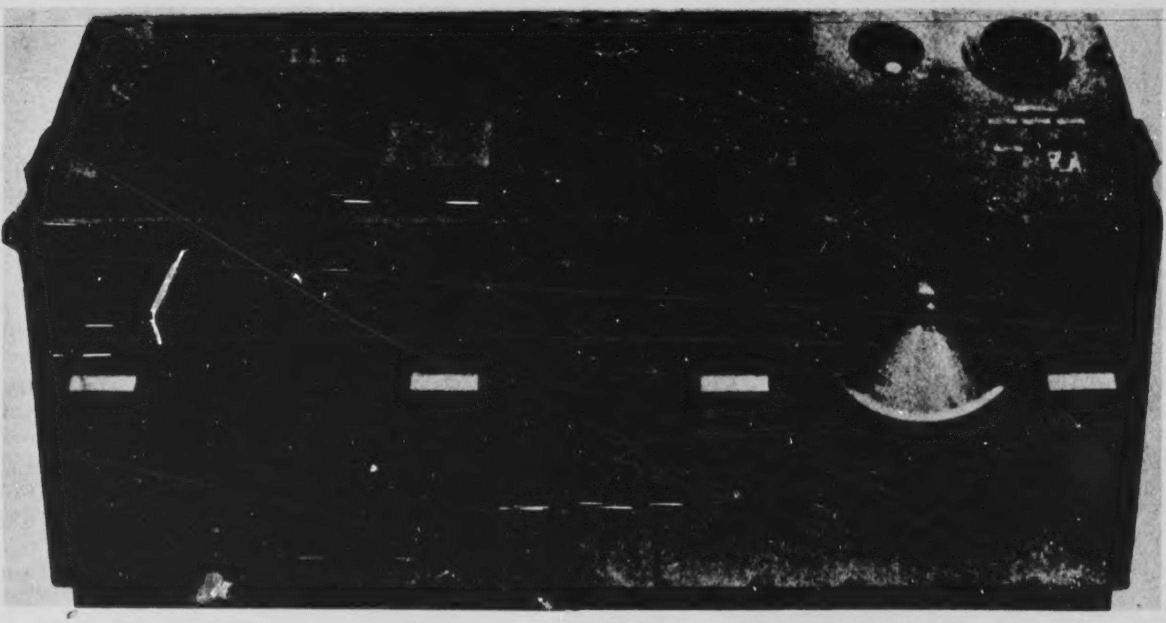
LIFT CONTROL.—The sensing instruments and the computer servo, mentioned in the preceding paragraph, compute fin order in terms of angle of attack of the fin with respect to the water, since a given fin at a specified speed through the water will produce a certain lift force. However, if the fins were only positioned to an angle with respect to the vessel, inaccurate lift forces would be applied to the ship. Even under moderate sea conditions, the following factors influence the actual angle of attack of the fin:

- Instantaneous pitch angle of the ship affects the load on the two fins in the opposite sense, increasing the angle of attack of one fin while decreasing that of the other.
- Motion of the fin due to ship's roll affects both fins in the same sense either increasing or decreasing the required angle.
- Heave or vertical motion of the ship as a whole affects the fins in the opposite sense similar to the effect caused by pitching.
- Orbital water flow in the vicinity of each fin introduces random variations in angle of attack.

Since these effects on the angle of attack are independent of each other, they can combine to produce a false angle of attack as great as 15 degrees. These false angles of attack are compensated for by measuring the actual lift produced by the fin. Using lift control, the fins can be tilted to produce a lift equal to ordered lift and the system continuously compensates for false angle of attack disturbances.

FIN LIFT.—The control system provides sensitivity adjustment to ship's motions, computation of ordered lift, and accuracy of stabilizing moment applied by the lift control feature.

The fins rarely operate in undisturbed water. The difference between the angle of water flow



27.351

Figure 18-11.—Bridge console.

with respect to the fin and the angle of the fin with respect to the ship (base line) is termed the false angle. False angles arise from wave action at the fin depth, and from various ship motions. Extreme false angle as great as 15 degrees are possible. The fins have an angular travel of ±30 degrees, so maximum permissible lift forces may be obtained in spite of false angles of attack. For example, at 20 knots with a fin angle of 26 degrees and an unloading false angle of 10 degrees, the expected lift would only be about 23.5 tons. False angle of attack of a fin at any given instant may be determined with reasonable accuracy from the algebraic difference between actual lift and the lift expected from a fin based on its angle with respect to the ship.

With the lift control system, each fin is continuously positioned to the fin angle that will maintain equality between ordered lift and actual lift, thus excluding false angle of attack disturbances.

CENTRAL OPERATIONS SYSTEMS

Advances in engineering technology, the use of solid state devices, and computer circuitry have made it possible to automate shipboard engineering plants. The automation concerns ship control and plant surveillance mainly. Though different types of automated engineering plants, or central operations systems, have been installed on Navy ships (mostly auxiliary ships), all major surface ships under construction will be equipped with some form of a central operations system. There will be no attempt here to describe each different system, but instead you will be given a general description of a respresentative central operations system.

GENERAL DESCRIPTION

The automated engineering plant brings together in one location all the major control functions and indications formerly located throughout the engineering spaces. Such a central operations system (COS) incorporates major advances in boiler control, turbine control and plant surveillance, and provides direct control of shaft speed and direction from a console located on the bridge of the ship. By means of the bridge throttle control, the OOD has a better feel of the ship and gets faster responses to desired changes. Moreover, fewer watchstanders are needed to operate the engineering plant.

Major units of the central operations system are shown in figure 18-9. The bridge and engineroom consoles control the propulsion plant. Information on plant conditions is provided by instrument displays, audible alarms indicating lights, meters, and printout typewriters.

Engineroom Console

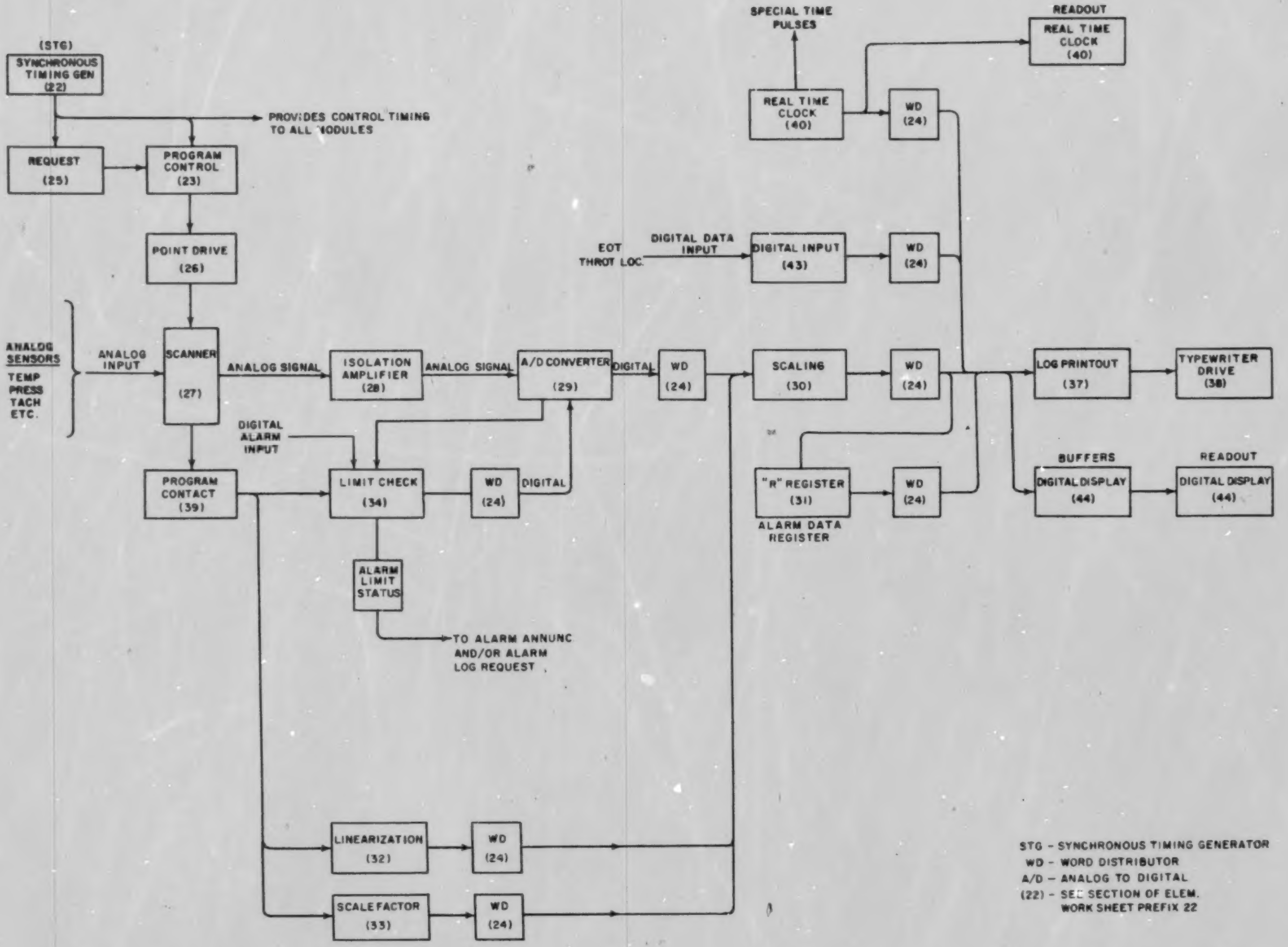
The engineroom console (fig. 18-10) is the heart of the COS, and is divided into five functional sections; generators, propulsion machinery, boilers, auxiliaries, and data logger. The desk top of each console section houses the controls and devices required to be within the operator's reach. The vertical surface above a desk top is used primarily for instrument display and visual indicators. Solid state control modules with printed circuit elements are used which can be easily removed from the panels by unplugging. Temperatures, pressures, and liquid levels are converted to electrical signals by sensors located at various points throughout the system.

Significant readings on the console are displayed on vertical scale, flush-mounted electric meters. Other readings which only need to be checked periodically are read on digital meters (called digital demand display readouts). Since the console monitors the boilers and monitors and controls the main propulsion plant, turbogenerator sets, main condensate pumps, lube oil pumps, fire pumps, and other auxiliary machinery. The engineroom operator can observe all important operating functions without leaving his station. At any time a 175-point plant status record may be made with the data logger.

The COS continually monitors over 200 key temperatures, pressures, levels and motor conditions. If any go beyond operating limits, the system sounds an alarm to alert the operator and the alarm logger automatically records the out-of-limit conditions. An alarm log review, plant status log, and bell log printout may be obtained at any time by pressing a pushbutton. Selected points also have individual alarm lights. A bell logger automatically records engine order telegraph signals and responses, propeller rpm, throttle control location, and throttle control wheel position together with time and date.

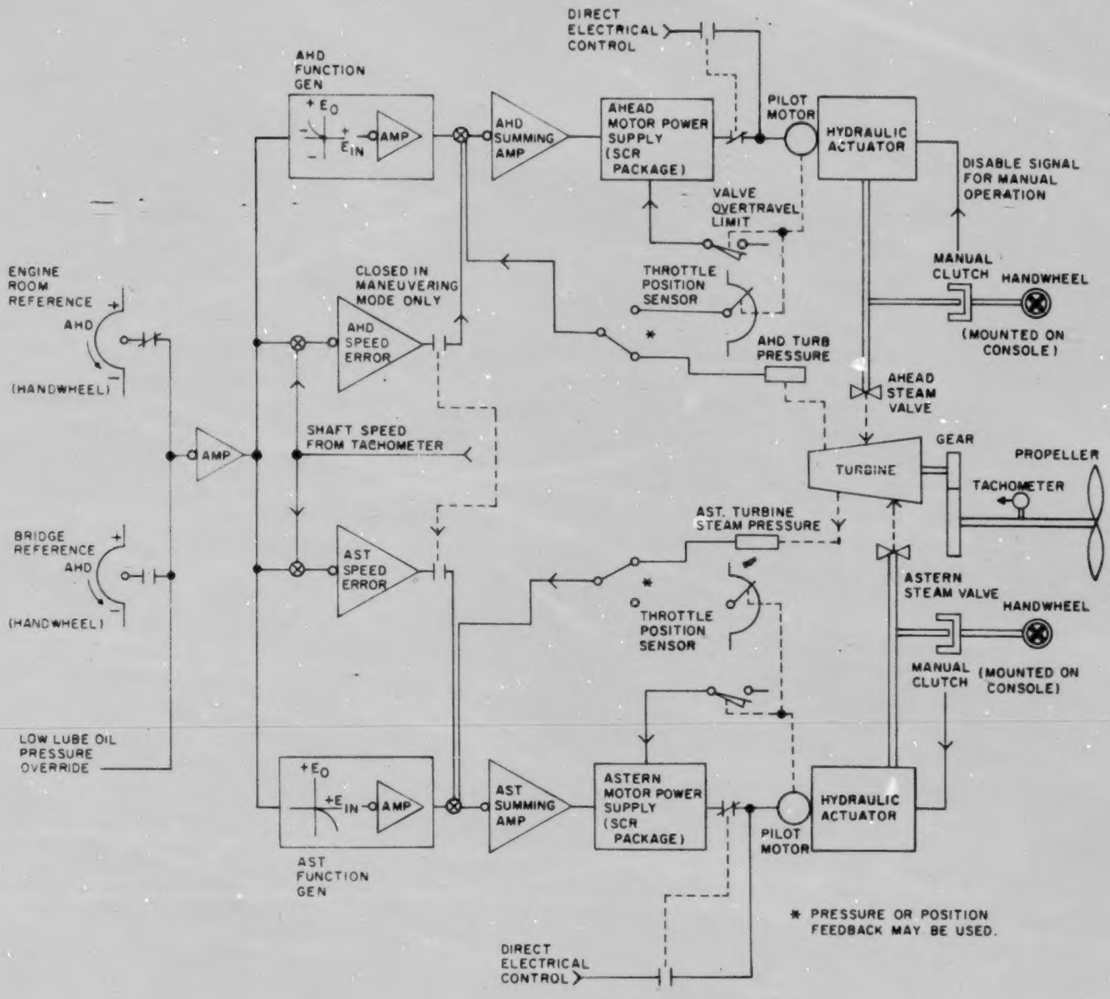
Bridge Console

The bridge console provides remote control of the throttle. The throttle control handwheel and other necessary equipment for control of


(STG)
SYNCHRONOUS TIMING GEN (22)
PROVIDES CONTROL TIMING TO ALL MODULES
REQUEST (25)
PROGRAM CONTROL (23)
POINT DRIVE (26)
ANALOG SENSORS
TEMP
PRESS
TACH
ETC.
ANALOG INPUT
SCANNER (27)
ANALOG SIGNAL
ISOLATION AMPLIFIER (28)
ANALOG SIGNAL
A/D CONVERTER (29)
DIGITAL
WD (24)
PROGRAM CONTACT (39)
DIGITAL ALARM INPUT
LIMIT CHECK (34)
WD (24)
DIGITAL
ALARM LIMIT STATUS
TO ALARM ANNUNC AND/OR ALARM LOG REQUEST
LINEARIZATION (32)
WD (24)
SCALE FACTOR (33)
WD (24)
SPECIAL TIME PULSES
REAL TIME CLOCK (40)
WD (24)
READOUT
REAL TIME CLOCK (40)
EOT
THROT LOC
DIGITAL DATA INPUT
DIGITAL INPUT (43)
WD (24)
SCALING (30)
WD (24)
"R" REGISTER (31)
ALARM DATA REGISTER
WD (24)
LOG PRINTOUT (37)
TYPEWRITER DRIVE (38)
BUFFERS
DIGITAL DISPLAY (44)
READOUT
DIGITAL DISPLAY (44)
STG - SYNCHRONOUS TIMING GENERATOR
WD - WORD DISTRIBUTOR
A/D - ANALOG TO DIGITAL
(22) - SEE SECTION OF ELEM. WORK SHEET PREFIX 22

140.94

Figure 18-12.—Block diagram of data scanner system.


DIRECT ELECTRICAL CONTROL
AHD FUNCTION GEN
+E0
+
EIN
AMP
AHD SUMMING AMP
AHEAD MOTOR POWER SUPPLY (SCR PACKAGE)
PILOT MOTOR
HYDRAULIC ACTUATOR
DISABLE SIGNAL FOR MANUAL OPERATION
VALVE OVERTRAVEL LIMIT
THROTTLE POSITION SENSOR
MANUAL CLUTCH
HANDWHEEL
(MOUNTED ON CONSOLE)
ENGINE ROOM REFERENCE
AHD
(HANDWHEEL)
CLOSED IN MANEUVERING MODE ONLY
AHD SPEED ERROR
*
AHD TURB PRESSURE
AHEAD STEAM VALVE
AMP
SHAFT SPEED FROM TACHOMETER
GEAR
PROPELLER
TURBINE
TACHOMETER
AST. TURBINE STEAM PRESSURE
BRIDGE REFERENCE
AHD
(HANDWHEEL)
AST SPEED ERROR
ASTERN STEAM VALVE
HANDWHEEL
THROTTLE POSITION SENSOR
MANUAL CLUTCH
(MOUNTED ON CONSOLE)
LOW LUBE OIL PRESSURE OVERRIDE
+E0
+EIN
AMP
AST SUMMING AMP
ASTERN MOTOR POWER SUPPLY (SCR PACKAGE)
HYDRAULIC ACTUATOR
PILOT MOTOR
AST FUNCTION GEN
* PRESSURE OR POSITION FEEDBACK MAY BE USED.
DIRECT ELECTRICAL CONTROL

140.95

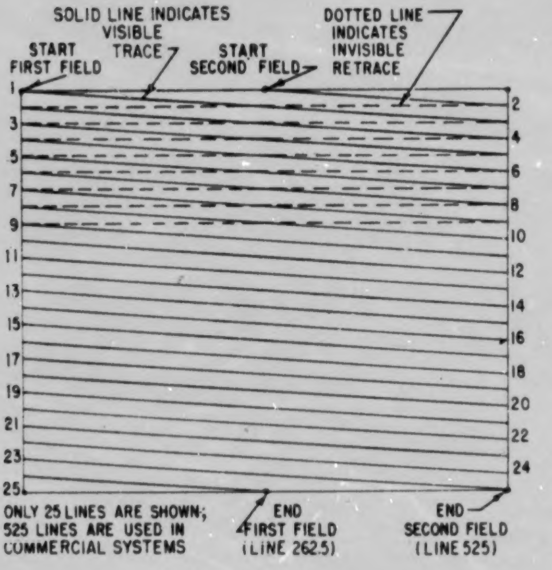
Figure 18-13.—Block diagram of throttle control system.

the propulsion plant are mounted on the left section of the console. The ship's helm and other steering and navigation equipment are mounted on the right section (fig. 18-11).

Sensors

The sensing devices used with the automated controls are in most cases improved versions of detectors already widely used throughout the fleet. In all cases the manufacturer's technical manuals for the system contain complete installation, operation, and maintenance instructions.

PRESSURE SENSORS.—Pressure sensors are used to convert plant pressure to an electrical signal for further transmission to the engineroom console. Two of the main types of sensors are the pressure-to-current transmitter and the pressure switch types.


SOLID LINE INDICATES VISIBLE TRACE
START FIRST FIELD
START SECOND FIELD
DOTTED LINE INDICATES INVISIBLE RETRACE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
ONLY 25 LINES ARE SHOWN; 525 LINES ARE USED IN COMMERCIAL SYSTEMS
END FIRST FIELD (LINE 262.5)
END SECOND FIELD (LINE 525)

7.99

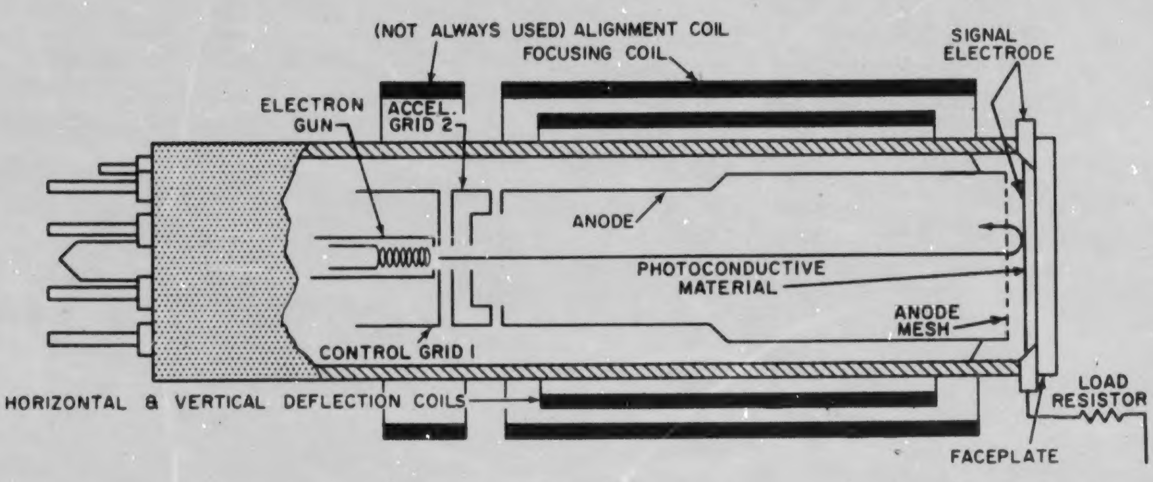
Figure 18-14.—Interlaced scanning.

LEVEL SENSORS.—Three types of level sensors are commonly used throughout the system. Since pressure may be a function of level, two of the devices are the pressure sensors just mentioned; the pressure-to-current transmitter for indication and the pressure switch for the alarm portion. Another level switch is used in bilges and unvented tanks. It operates in much the same way as the float switch described in chapter 3.

TEMPERATURE SENSORS.—Temperature is measured by means of resistance temperature detectors (RTD). An RTD consists of a sensing element incased in a protective tube. Since the electrical resistance of the element changes with temperature changes, the temperature can be determined by measuring the resistance. In most installations the RTD fits into a thermo well which is bored and threaded to receive the detector.

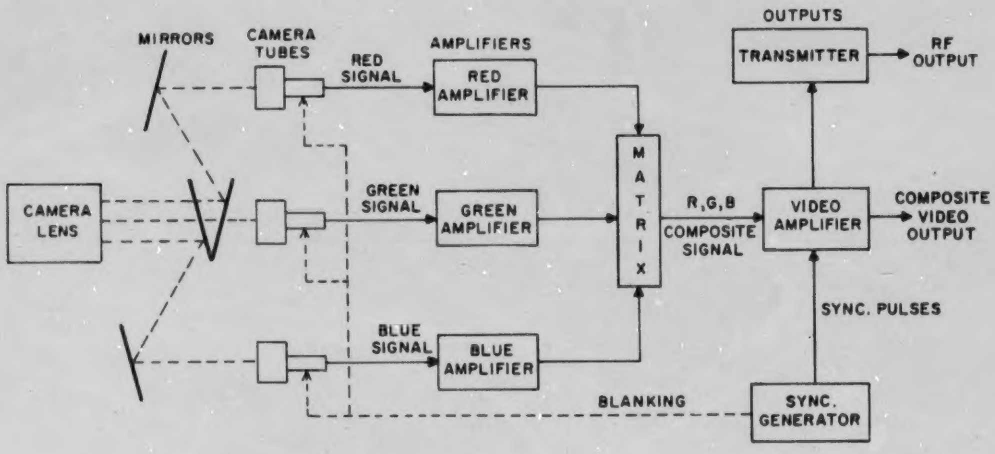
Data Scanner System

Figure 18-12 is a block diagram of the data scanner system. The inputs from the sensing devices are placed into the scanner (block 27) as analog values. The scanner is an electronic selector governed by the synchronous timing generator (22), the program control (23) and the point drive (26). When there are no requests


(NOT ALWAYS USED) ALIGNMENT COIL
FOCUSING COIL
SIGNAL ELECTRODE
ELECTRON GUN
ACCEL. GRID 2
ANODE
PHOTOCONDUCTIVE MATERIAL
ANODE MESH
CONTROL GRID 1
HORIZONTAL & VERTICAL DEFLECTION COILS
LOAD RESISTOR
FACEPLATE

7.96

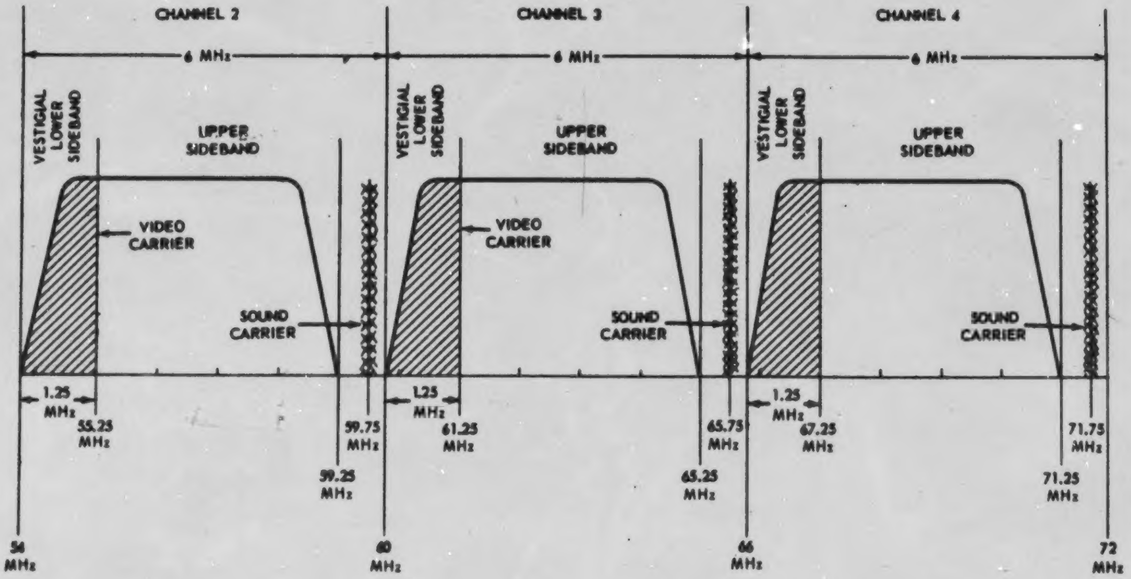
Figure 18-15.—Structure of vidicon tube.


MIRRORS
CAMERA TUBES
RED SIGNAL
AMPLIFIERS
RED AMPLIFIER
OUTPUTS
TRANSMITTER
RF OUTPUT
CAMERA LENS
GREEN SIGNAL
GREEN AMPLIFIER
MATRIX
R,G,B
COMPOSITE SIGNAL
VIDEO AMPLIFIER
COMPOSITE VIDEO OUTPUT
SYNC. PULSES
BLUE SIGNAL
BLUE AMPLIFIER
BLANKING
SYNC. GENERATOR

140.185

Figure 18-16.—Typical color camera.

for the system, such as the bell log, alarm log, status log, or display triggers, the scanner continues to check each of the inputs. If there is a request present, the scanner will go directly to the address requested and process that signal before monitoring all the addresses. The signal is sent to the isolation amplifier (28) from the scanner and, after amplification, to the analog digital converter (29). The program contact (39) controlled by the scanner, sets up the comparison


CHANNEL 2
CHANNEL 3
CHANNEL 4
6 MHz
6 MHz
6 MHz
VESTIGIAL LOWER SIDEBAND
UPPER SIDEBAND
VIDEO CARRIER
SOUND CARRIER
VESTIGIAL LOWER SIDEBAND
UPPER SIDEBAND
VIDEO CARRIER
SOUND CARRIER
VESTIGIAL LOWER SIDEBAND
UPPER SIDEBAND
SOUND CARRIER
1.25 MHz
55.25 MHz
59.75 MHz
59.25 MHz
1.25 MHz
61.25 MHz
65.75 MHz
65.25 MHz
1.25 MHz
67.25 MHz
71.75 MHz
71.25 MHz
54 MHz
60 MHz
66 MHz
72 MHz

40.218

Figure 18-17.—RF spectrum for TV channels 2, 3, and 4.

values for the signal as well as any adjustments to the signals required during conversion and scaling.

If the information is requested or the point is in alarm, the A/D converter then transfers the values via the word distributor (24) to the scaling module. If neither of the previously mentioned conditions exists, the scanner executes branch back and picks up the next address and repeats the process.

After the information leaves the A/D converter it is sent to the scaling module which scales all signals into a zero to 1000 scale. This information is in the form of pulses numbered from zero to 1000 according to the value of the input signal to the A/D converter. The address information is then placed in the necessary registers and along with inputs from the real time clock (40) and digital input (43) and made ready to be sent to the log printout (37) and on to the typewriter drive (38) for printing.

Information leaving the scaling module for display is sent directly to the digital display buffers and readouts (44) and appear at the readout units on the console face.

The entire operation from pickup of the input address to activation of the printout units requires a time span of 0.0376 milliseconds. The assembly will monitor the complete bank of 273 inputs in approximately two seconds provided there are no requests or alarms conditions presented to the system during that time period.

Throttle Control

Figure 18-13 is a block diagram of the throttle control system. A reference input signal may be taken from either the bridge or engineroom reference handwheel potentiometer and fed to the system. Negative voltages are used for ahead speeds and positive for astern. The signal then passes through a common operational amplifier where it is inverted and then goes to the common circuit for both the ahead and astern turbines. The functions generators will accept only a signal of a given polarity. The ahead function generator accepts positive signals and the astern function generator negative signals. The signal to the function generator is also used as a reference signal for the speed feedback system. This circuit compares the reference and speed feedback signals and uses the algebraic sum as the input to the speed error amplifier.

The signal to the function generator is adjusted within the aplifier so that the output is equivalent to the cube of the input. This is done to change the linear movement of the reference to the nonlinear characteristics of the throttle valve. Inversion once again takes place in the function generator.

The output of the function generator is matched with the speed error signal and the throttle position signal at the summing junction and the algebraic sum is fed to the summing amplifier. Inversion takes place and the output controls the action of the SCR power package.

The SCR power package will cause the pilot motor to drive in either direction depending upon the input. A positive input will cause the pilot motor to drive in a direction to open the throttle valve. A negative input will close the throttle valve. The SCR power package will be inhibited by limit switches if the motor travel exceeds a predetermined point of travel.

The pilot motor positions a pilot valve in the hydraulic actuator which ports oil in the proper direction to correctly position the throttle valve.

A reference signal for throttle position, which is controlled by the pilot motor, is fed back to the summing junction. This section cancels the input signal when the desired valve opening is reached.

During direct electrical control of the throttle, the contacts in the throttle location switch change the circuitry eliminating the regulated signal and setting up the circuitry for signals from the direct throttle switches.

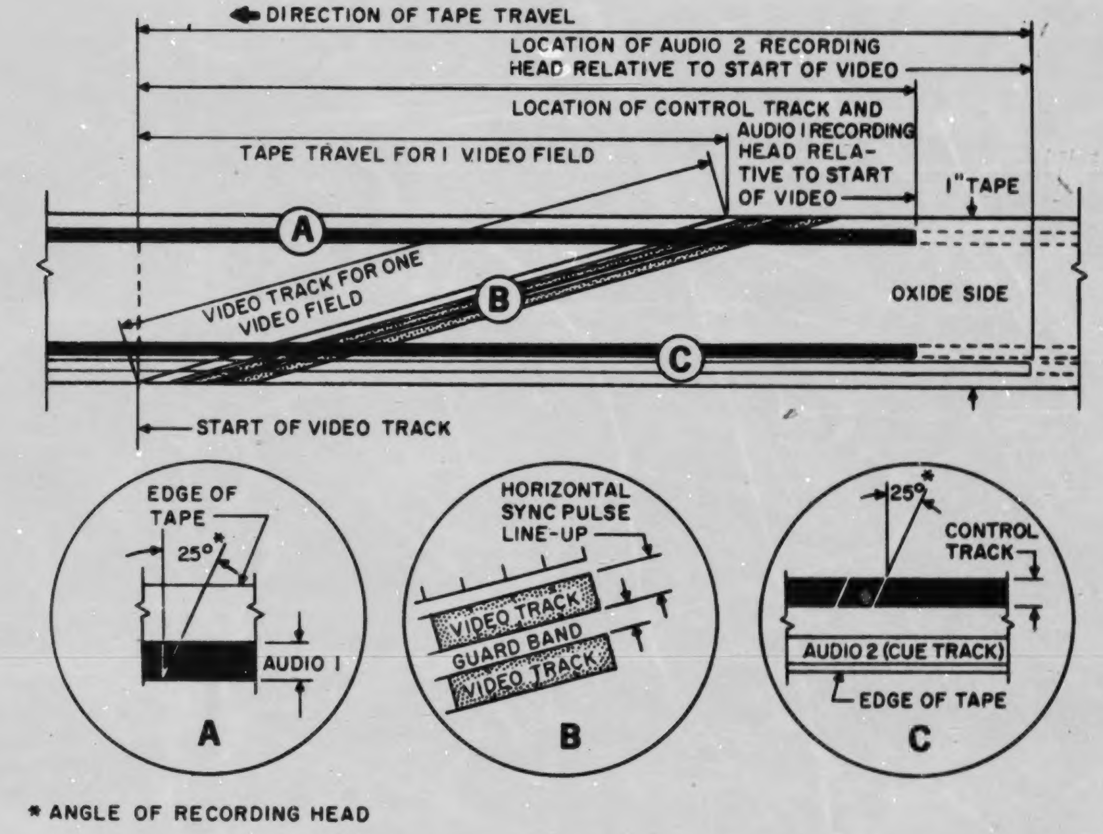
During manual operation, the manual clutch is engaged and the hydraulic actuator is inhibited. In addition, the hydraulic system is vented to prevent a hydraulic lock and permit the movement of the handwheel for manual throttle control.

A tachometer generator on the shaft produces an output signal that is fed back as the speed error signal. This signal produces a rapid response from the system when the engineering plant is in the maneuvering mode. Under normal mode of plant operation the speed feedback signal is not utilized.

The signals for astern throttle movement are handled in the same manner but all the polarities are reversed.

TELEVISION

New developments in television have made possible applications other than the usual ones of informing and entertaining the viewing public. Civilian and military establishments are now using TV for surveillance, traffic contro, instruction, and other purposes. Typical applications include the monitoring of congested traffic areas,


DIRECTION OF TAPE TRAVEL
LOCATION OF AUDIO 2 RECORDING HEAD RELATIVE TO START OF VIDEO
LOCATION OF CONTROL TRACK AND AUDIO I RECORDING HEAD RELATIVE TO START OF VIDEO
TAPE TRAVEL FOR I VIDEO FIELD
1" TAPE
A
VIDEO TRACK FOR ONE VIDEO FIELD
B
OXIDE SIDE
C
START OF VIDEO TRACK
EDGE OF TAPE
25°*
AUDIO I
A
HORIZONTAL SYNC PULSE LINE-UP
VIDEO TRACK
GUARD BAND
VIDEO TRACK
B
25°*
CONTROL TRACK
AUDIO 2 (CUE TRACK)
EDGE OF TAPE
C
* ANGLE OF RECORDING HEAD

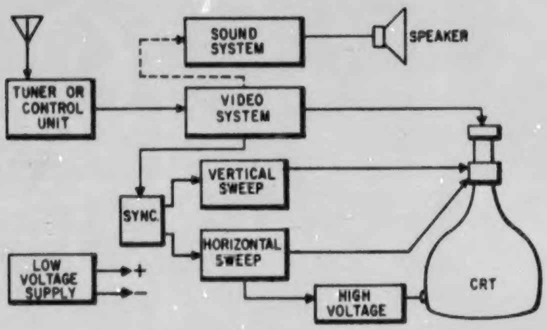
140.186

Figure 18-18.—Tape format.

zones of combat, and hazardous or inaccessible locations, such as radioactive spaces and ship bottoms. The Navy, in particular, is using closed circuit television to great advantage for training its officers and enlisted men, landing its aircraft on carriers, and entertaining its shipboard personnel at sea.

SCANNING

As in motion-picture films, television presents on a screen a series of pictures, such that each picture of the series differs slightly from the preceding one. The sensation produced by one picture remains until the next picture appears. In the way the pictures are made to appear, the viewer is unaware of any interruption between pictures. The television technique for producing this sensation and the illusion of motion is called interlace scanning. Each picture is made up of 525 lines of information transmitted at the rate of 30 complete pictures a second, which eliminates flicker. Figure 18-14 shows how the entire screen (picture tube face) is scanned from left to right and top to bottom. An electronic beam scans the entire tube face twice in order to get one complete picture. The scanning starts with line No. 1 at the top left-hand corner of the screen



40.234
Figure 18-19.—TV receiver/monitor block diagram.

(viewed from the front) and continues to the right and slightly downward until the right side of the screen is reached. Then the beam is cut off and moved back (dotted line) to the left side of the screen where it is turned on for the scan of line No. 3. This action is continued for all the odd-numbered lines in the first field which ends at midscreen on line No. 525, where the beam if cut off and deflected back to the top center at line No. 2 to start a second field. Then the beam will scan all the even-numbered lines through No. 524. The electronic beam that scans the screen also tranfers the picture into electrical signals. The signals are transmitted to a receiver where the scanning process is reversed. At the receiver each line is reproduced in its proper position as transmitted. The scanning in the receiver is synchronized with the transmitter (camera) scanning signal.

BANDWIDTH

The bandwidth for a transmission system corresponds to the number of bits of information, or detail, that can be transmitted per second. The bandwidth is sufficient to carry enough bits of information to distinguish between black and white, without any gray in between, or to prevent fading of color when there should be a sharp color line on the screen.

A checkerboard (test) pattern or a resolution chart is used to check the system for the standard 525 lines, the vertical detail, and the ASPECT RATIO (picture width to height) required to ensure that the vertical-to-horizontal deflection is proportional.

FREQUENCIES

The frequencies assigned to television channels 2 through 13 range between 54 and 216 MHz, which are called the very high frequencies (VHF); channels 14 through 83 are assigned the ultrahigh frequencies (UHF) between 470 and 890 MHz. Each channel is alloted a 6-MHz bandwidth which consists of synchronizing signals and video and audio information for transmission from the TV camera to the receiver.

TV CAMERAS

Most closed-circuit television systems use a small, simply constructed camera tube or vidicon (fig. 18-15). Besides being small, the vidicon camera is simple to operate and adjust.

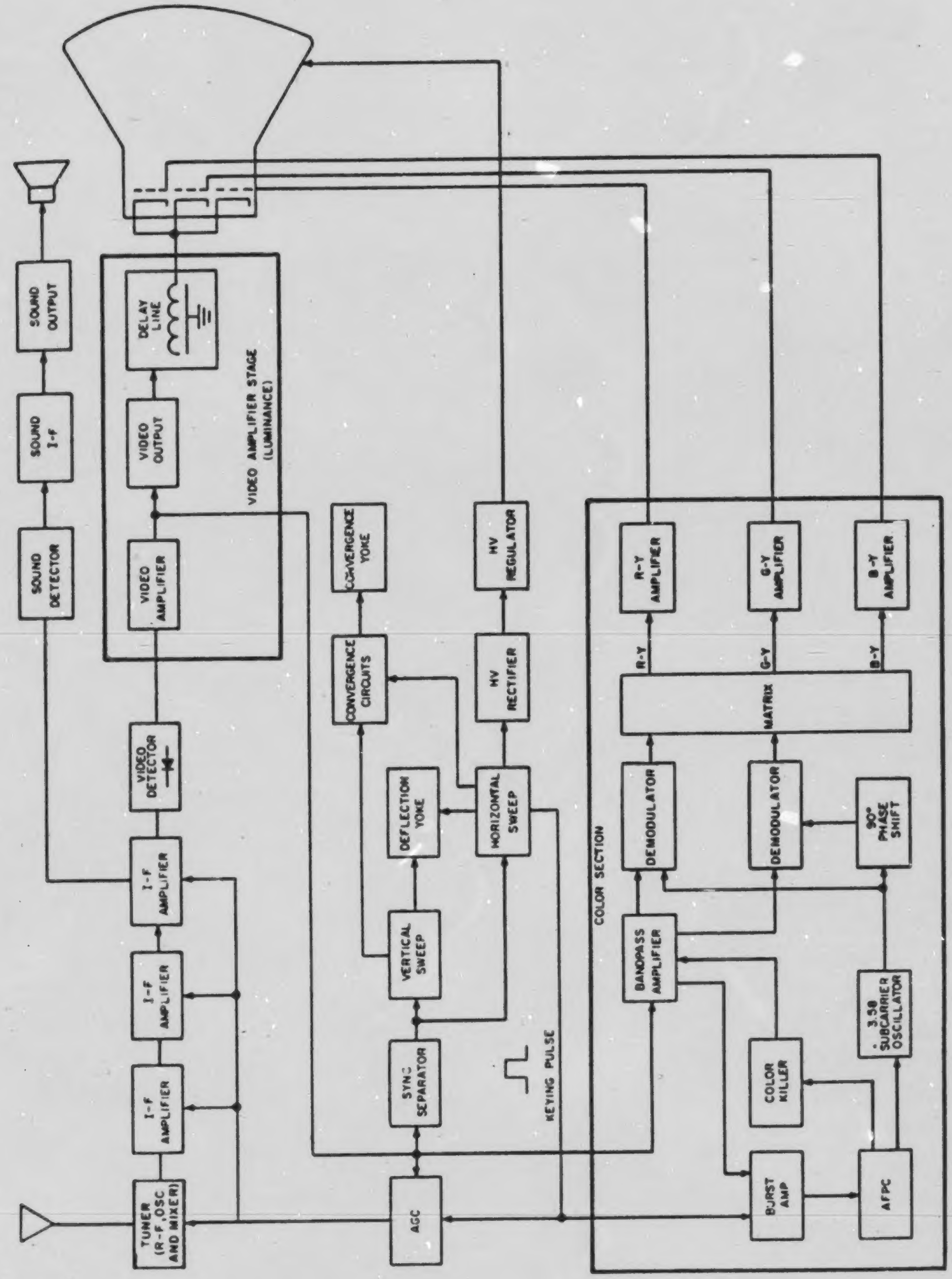
Television cameras, whether black and white or color, operate much in the same manner. The black-and-white camera has only one tube and one scanning beam, whereas the color camera has three separate tubes and three separate beams (fig. 18-16) all of which scan both vertically and horizontally at exactly the same instant. The three separate color signals (red, green, and blue) are amplified by an adjacent video amplifier and then electrically combined to produce a single complex video signal. To this signal is added a reference signal (called the COLOR BURST or color subcarrier signal) which synchronizes the color portion of the TV receiver to the camera so that the reproduction of a scene will be as lifelike as possible.

TRANSMISSION

Picture or VIDEO transmission on all television systems is amplitude modulated (AM) and vestigial sideband (one sideband of the carrier is transmitted, and only part of the other sideband is transmitted). Actually a bandwidth of 9 MHz is reduced to 6 MHz to allow the use of more channels over a given frequency range (fig. 18-17).

The method of transmission used in the U.S. (called negative modulation transmission) minimizes the effects of noise during synchronizing signal reception and has an advantage of less transmitted power with an increase in picture brightness. There are other countries that use positive modulation transmission which results in a negative picture on an American-made TV set.

Sound or AUDIO is transmitted by a separate transmitter-frequency modulation (FM) at 4.5


SOUND OUTPUT
SOUND I-F
SOUND DETECTOR
DELAY LINE
VIDEO OUTPUT
VIDEO AMPLIFIER
VIDEO AMPLIFIER STAGE (LUMINANCE)
VIDEO DETECTOR
I-F AMPLIFIER
I-F AMPLIFIER
I-F AMPLIFIER
TUNER (R-F, OSC AND MIXER)
CONVERGENCE YOKE
CONVERGENCE CIRCUITS
DEFLECTION YOKE
VERTICAL SWEEP
SYNC SEPARATOR
AGC
HV REGULATOR
HV RECTIFIER
HORIZONTAL SWEEP
KEYING PULSE
COLOR SECTION
R-Y AMPLIFIER
G-Y AMPLIFIER
B-Y AMPLIFIER
R-Y
G-Y
B-Y
MATRIX
DEMODULATOR
DEMODULATOR
90° PHASE SHIFT
BANDPASS AMPLIFIER
3.58 SUBCARRIER OSCILLATOR
COLOR KILLER
BURST AMP
AFPC

40.242

Figure 18-20.—Color television receiver, block diagram.

MHz above the video carrier on all channels. The maximum deviation (bandwidth) of the audio carrier signal can be no more than 25 kHz on either side of the carrier.

VIDEO TAPE RECORDINGS

Television programs are often recorded on video tape for rebroadcast at a later time or for prerecording programs, reruns, and special events. In video tape recording, TV sound and picture are put on a magnetic tape. There are four tracks: one for the video signals, another for control, and two for audio signals. The video track (fig. 18-18B) angles across the tape at about 45 degrees to its edge.

The control track (fig. 18-18C) ensures that the tape is played back at the same speed as it was recorded with no interference or loss of information, such as video, sync signals, or color.

Audio 1 (fig. 18-18A) is the sound track associated with the taped video signals. Audio 2 (fig. 18-18C) is a so-called cue track that provides the operator/director with information; it may also record sound for use at a later date.

Video recording/reproducing heads number from one to four, depending on whether the recording is made across the tape or at an angle to it. There is a separate reproducing/recording head for each audio or control track.

COLOR RECEIVERS

Color TV receivers are capable of reproducing color scenes or black-and-white scenes if necessary. If a black-and-white scene is to be televised, the color burst is removed from the video signal, inhibiting or cutting off the three color guns. During a color scene, the color burst allows the three guns to produce the required colors as seen at the camera.

Figure 18-19 and 18-20 are black diagrams of typical black-and-white and color TV receivers, respectively.

CHAPTER 19

CLOSELY REGULATED POWER SUPPLIES

The interior communications and weapons systems aboard modern Navy ships require closely regulated electric power for proper operation. Special motor-generator (m-g) sets supply the greater part of this closely regulated power. Static inverters and converters are replacing m-g sets in some installations. This chapter discusses briefly the electrical characteristics for types I, II, and III a-c power systems, and then follows with a discussion of a closely regulated m-g set, a static inverter, a d-c rectifier power supply unit, and a no-break power supply unit. Each of these units is typical or representative of those installed aboard ship. Because equipage in special power applications aboard ship is so diverse, little is said about troubleshooting or maintenance. In studying this chapter, you should review the operating principles of electric/electronic components used in closely regulated power supply systems.

TYPES OF POWER SUPPLIES

Mil-Std-761A (Ships) of 11 Oct 1963 establishes standard electrical characteristics for AC power systems. As shown in table 19-1, the power system characteristics are those existing at the load, and do not represent generator output characteristics.

Present ship service generators and distribution systems are adequate for 60- and 400-hertz type I power. Type II power differs principally from type I in having more stringent voltage requirements. Better voltage regulation at the ship service generator will not satisfy these voltage requirements, as the specified voltage is at the equipment, not at the generator output. Static type line voltage regulators placed at the equipment are being used in some installations to provide type II voltage control. Electric speed governors for ship service generators are also being used to provide type II frequency control. Special closely regulated m-g sets are used on most ships to supply type III power.

30 KW CLOSELY REGULATED MOTOR GENERATOR SET

As presently writen, the specifications for motor generators with a 400-hertz output divide these units into:

Type 1 — General Purpose (arrangement A or B).
Type 2 — Special Purpose — with voltage balance regulators (arrangement A or B).
Arrangement A — With meters and switches.
Arrangement B — without meters and switches.

One unit of the most stringent type, Type 2, Arrangement A, is the 30 KW 440/450 VAC, 60/400-hertz, 3-phase unit herein described and shown in figure 19-1.

The set consists of a wound rotor induction motor driving a synchronous generator. Internal control circuits include voltage and frequency regulating systems, a motor controller (magnetic starter), and generator output circuit breakers. The unit is designed for parallel operation with an identical unit. Its housing is dripproof.

The wound rotor motor and generator is a two bearing unit with motor and generator rotors, plus a self-cooling fan mounted on a single shaft. The single row ball bearings are prelubricated, double sealed, double row width, and a "Warning Do Not Lubricate Bearings" instruction plate mounted on the unit.

MOTOR GENERATOR

In a 30 KW motor generator, since a constant speed is required for a constant frequency, the change in current for changes in torque

Table 19-1—Standard Electrical Characteristics for Shipboard A-C Power Systems

	Type I	Type II	Type III
A. Nominal utilization voltage	115 or 440	115 or 440	115, 115/200, or 440
B. Nominal frequency	60 or 400 Hz	60 or 400 Hz	400 Hz
C. Steady state voltage			
1. Steady state tolerance band			
a. Average line to line voltage for 3 phase	±5%	±1%	±1/2%
b. Line to line voltage for single phase of 3 phase system	±8%	±3%	±1/2%
2. Unbalance between phases	3%	2%	1%
3. Modulation amplitude (Note 1)	2%	2%	1%
D. Transient voltage			
1. Transient voltage limits	±18%	±18%	±5%
2. Recovery time	2 sec.	0.25 sec. at 400 Hertz 0.75 sec. at 60 Hertz	0.25 sec.
E. Steady state frequency band	±5%	±5%	±1/2%
F. Transient frequency			
1. Transient frequency limits (Note 2)	±3%	±3%	±1%
2. Recovery time	2 sec.	2 sec.	0.25 sec.
G. Waveform			
1. Total harmonic content	5%	6%	3%
2. Maximum single harmonic	3%	4%	2%
3. Deviation factor	-	-	5%

Note 1: Not included in steady state limits.

Note 2: With frequency transients of 3%, only 1% shall be outside the steady state frequency tolerance band for Types I and II power.

40.184

requirement is accomplished through the external means of varying the firing angle of three SCRs (Silicon Controlled Rectifiers).

The basic operation of a silicon controlled rectifier is as follows. The silicon controlled rectifier (SCR) has a PNPN device structure and is the semiconductor equivalent of a gas thyratron. It is constructed by making both an alloyed PN junction and a separate ohmic contact to a diffused PNP silicon pellet. Schematic representation of the SCR is shown in figure 19-2. With reverse voltage (encircled polarities) impressed on the device (cathode positive), it blocks the flow of current as in an ordinary rectifier. With positive voltage applied to the anode (uncircled polarities), the SCR blocks the flow of current until either the forward breakdown voltage is reached, or a suitable gate pulse is applied to the gate. In practical application, the positive pulse applied to the gate is used to control the

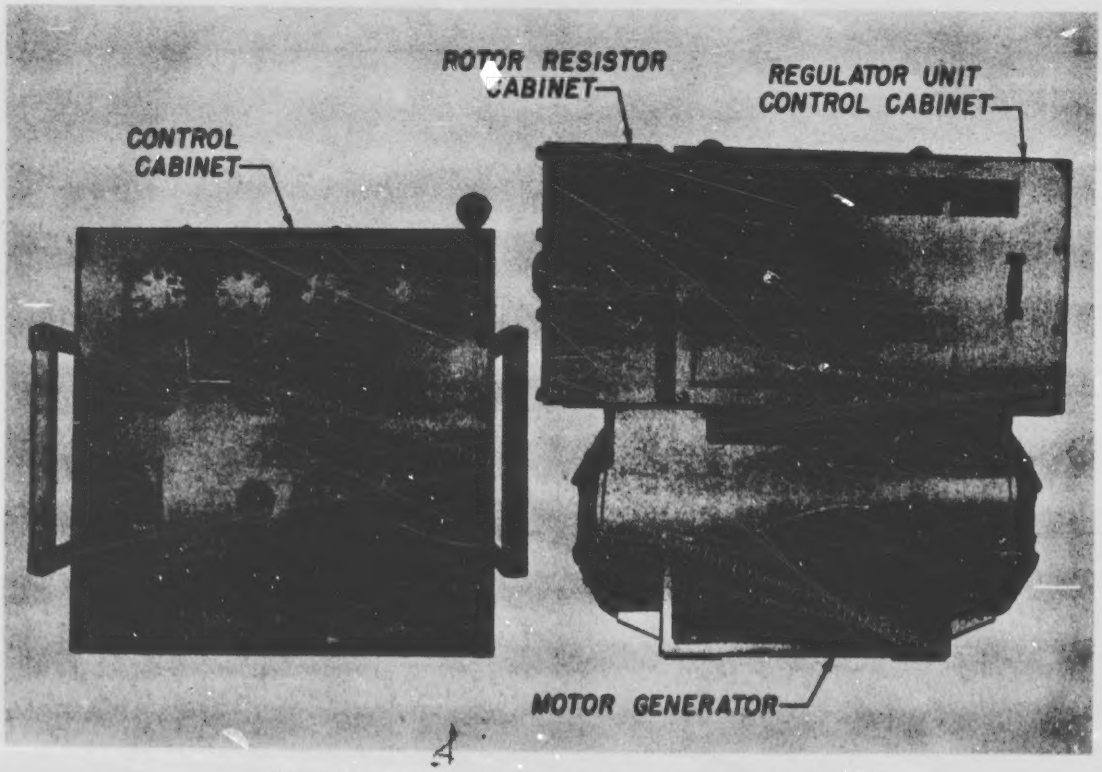


Figure 19-1.—Motor generator set with control equipment. 40.111

firing of the SCR. At this point the SCR switches into a high conduction state, the current flow is limited only by the external circuit impedance and supply voltage. The magnitude of gate impulse needed to turn on an SCR varies with temperature and also from unit to unit. Precise firing is attained by a short gate pulse with an amplitude of at least three volts and is capable of delivering the maximum firing requirements of the SCR.

In the following discussion, short SCR firing time allows a small rotor current to flow, thus limiting the torque developed by the rotor to that required to maintain rated speed (necessary for 400 Hz) at no load or light loads. As torque load is increased, a greater current is allowed to flow in the rotor, thus maintaining rated speed at increased torque demand.

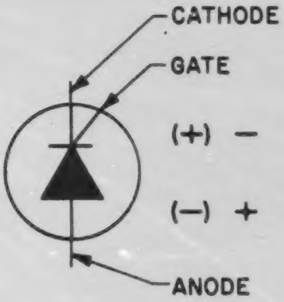
Since the synchronous speed of the stator flux is directly proportional to the input frequency of the supply to the motor, a change is necessary in the rotor torque to maintain constant speed for this variation also. The frequency regulator supplies the proper triggering pulse to the rotor SCRs thus controls the current flow in the rotor hence controls the speed of the motor.

CONTROL EQUIPMENT

The motor control consists of an alternating-current magnetic starter containing overload protection; "start" and "stop" switches and a frequency regulating system. The first two components are standard, however, the frequency regulating system is further divided into a detector, a preamp and trigger, a starter, a motor rotor control unit, and a resistor unit (fig. 19-3).

FREQUENCY REGULATOR

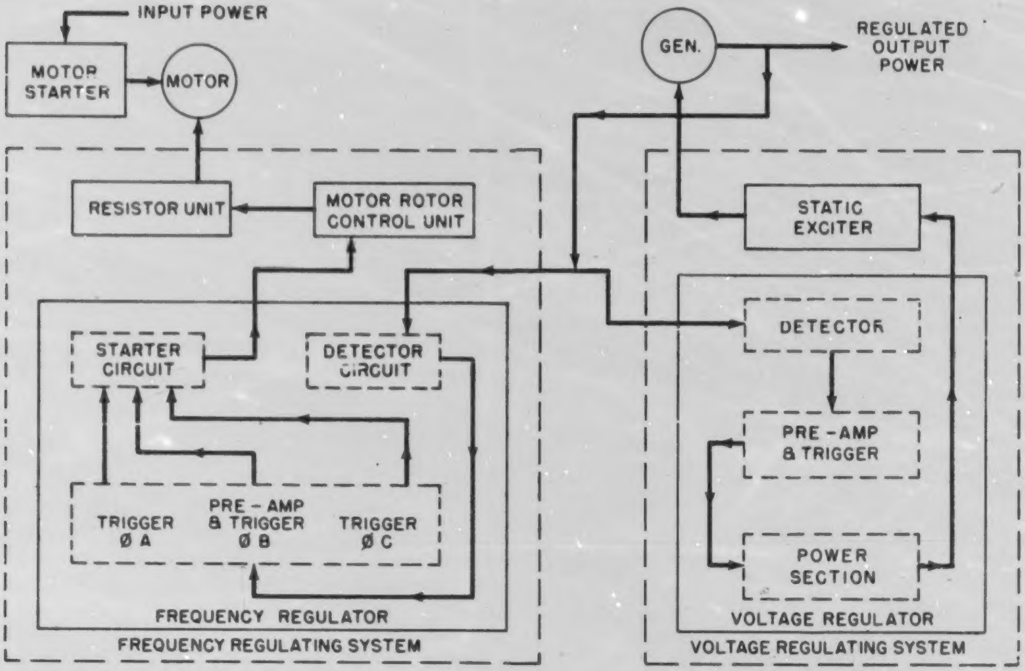
The detector in the frequency regulating system is primarily a frequency sensing


CATHODE
GATE
(+) −
(−) +
ANODE

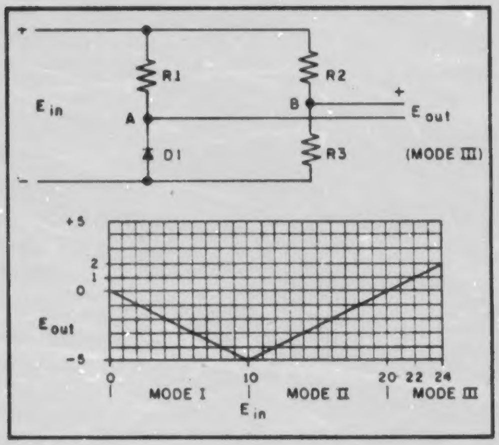
40.112
Figure 19-2.—Schematic symbol silicon controlled rectifier.

transformer whose voltage output varies linearly on changes in generator output frequency rather than output voltage. The signal voltage obtained from the frequency sensing transformer is rectified, filtered, and compared in a Zener reference voltage divider, all container within the detector circuit. This circuit provides an interesting application of Zener diodes as shown in figure 19-4. The purpose of the Zener reference bridge is to compare a high supply voltage with a reference voltage, and provide a low amplitude output signal voltage to be used as a base drive for a transistor.

The Zener reference bridge consists of resistors R1, R2, and R3 and Zener diode D1 as shown in figure 7-4. Resistors R1, R2, and R3 are equal, and the Zener diode D1 has a breakdown rating of 10 volts. When E_{in} is equal to or less than 10 volts, negligible current will flow through R1 and the bridge is operating in mode I as shown on the graph in figure 19-4. As E_{in} rises above 10 volts, the voltage drop across D1 remains constant at 10 volts and the current through R2 and R3 increases, increasing the voltage drop across R2 and R3. At E_{in} equal to 20 volts, the drop across resistors R1, R2, and


INPUT POWER
MOTOR STARTER
MOTOR
GEN.
REGULATED OUTPUT POWER
RESISTOR UNIT
MOTOR ROTOR CONTROL UNIT
STATIC EXCITER
STARTER CIRCUIT
DETECTOR CIRCUIT
DETECTOR
PRE-AMP & TRIGGER
TRIGGER Ø A
PRE-AMP & TRIGGER Ø B
TRIGGER Ø C
POWER SECTION
FREQUENCY REGULATOR
FREQUENCY REGULATING SYSTEM
VOLTAGE REGULATOR
VOLTAGE REGULATING SYSTEM

40.113
Figure 19-3.—Block diagram of current flow.



40.114

Figure 19-4.—Zener reference bridge.

R3 is 10 volts so that E_{out} is zero. When E_{in} is between 10 volts and 20 volts, the bridge is in mode II as shown on the graph in figure 19-4. As E_{in} rises above 20 volts, the voltage at point B will rise above 10 volts, however, the voltage at point A will remain at 10 volts and potential differences between points B to A will increase. For E_{in} greater than 20 volts the bridge is in mode III, which is the normal operating mode.

Consider the input voltage E_{in} to be 22 volts, then the output voltage will be 1 volt. Next consider the input voltage E_{in} to be 24 volts, then the output voltage will be 2 volts. Although the input voltage is 22 volts to 24 volts, the output voltage is only 1 volt to 2 volts. Therefore, without adding additional components to lower the voltage to the point where it can be used as a base drive for a transistor, the output voltage of the bridge can be used as a base drive for a transistor.

The signal leaving the Zener bridge is amplified by two DC transistor amplifiers also in the detector before presentation to the preamp and trigger (fig. 19-3).

The purpose of the preamp and trigger is to amplify and connect the varying DC input voltage into controlled pulses of sufficient amplitude to fire the SCRs.

In the trigger circuit, the signal amplitude (now pulses) controls the firing point of the SCRs in the motor rotor control circuit (which are in series with large, about 3000W resistors), are controlled. Thus, control is exerted on the motor rotor.

VOLTAGE REGULATING SYSTEM

The voltage regulating system is composed of the voltage regulator and the static exciter (fig. 19-3). The voltage regulator, receives its signal from the generator output. The static exciter receives its signal input from the power section in the voltage regulator.

The operation of the detector in the voltage regulator is similar to that of the frequency regulator, in that the detector senses a change in generator output, however, the change is in voltage rather than frequency. The increase or decrease in voltage is rectified, filtered, and compared prior to amplification. Again the comparison is on a Zener reference bridge prior to amplification in DC amplifiers.

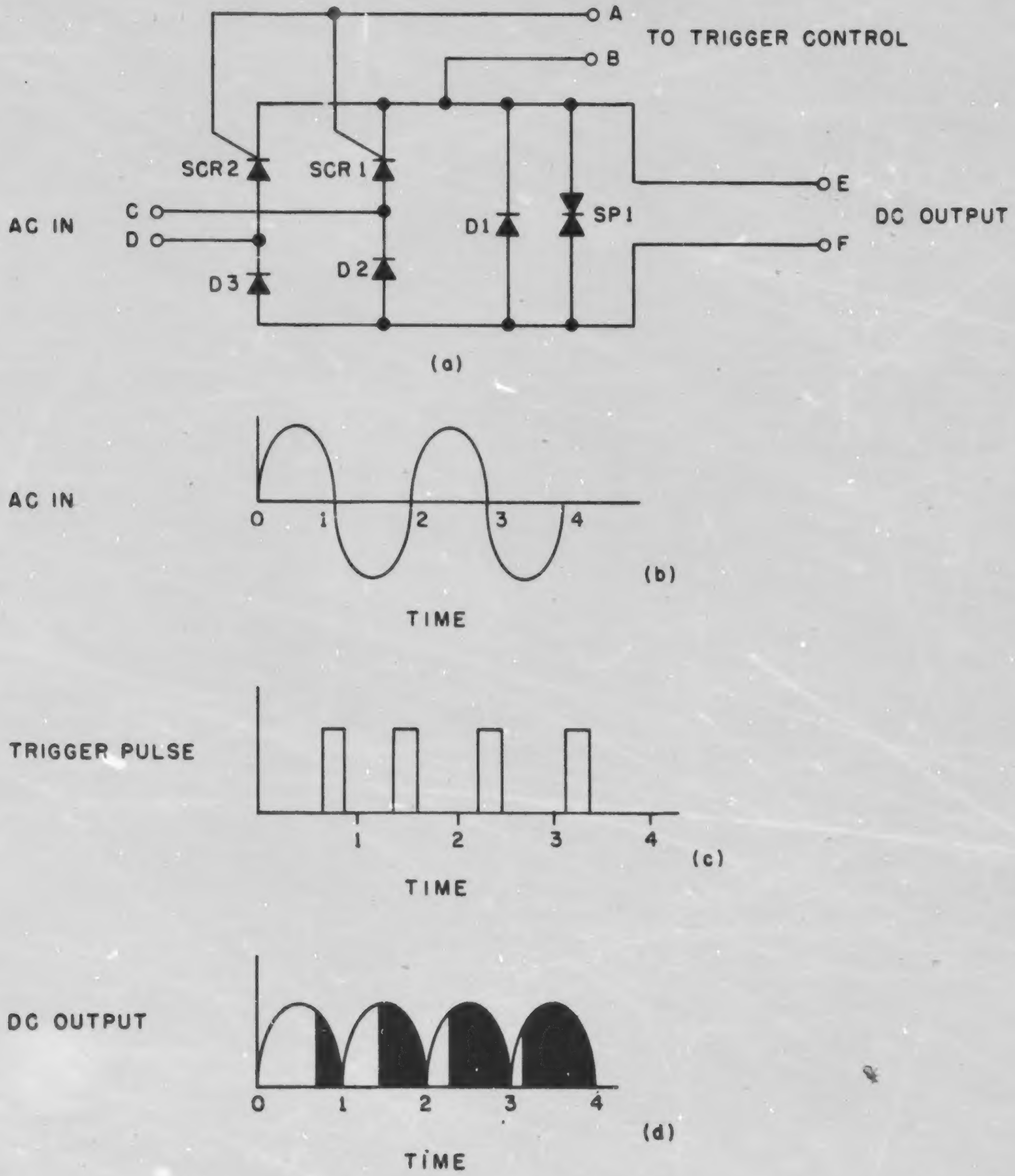
The preamp and trigger operate essentially as described in the section under frequency regulation, except that in this case the signal is fed to a power section.

The power circuit provides an application of SCR operation. This section (fig. 19-5) consists of three diodes (D1, D2, and D3) and two SCRs (SCR1 and SCR2). D2, D3, SCR1, and SCR2 are connected in the normal full-wave rectifier bridge manner. No current will flow out of the bridge (between points E and F) until the SCRs receive a trigger pulse at the gates which will turn the SCRs on. Assume that during the first half cycle of applied AC voltage (time 0 to 1), SCR1 has its anode positive with respect to cathode and a trigger pulse is applied to terminals A and B. SCR1 will conduct current and SCR2 will block current, like a normal rectifier bridge, for the remainder of the applied half cycle as shown in figure 19-5d. Diode D1 and thyrector SP1 (a General Electric silicon controlled diode used for AC surge protection), are used to protect the circuit from transients and voltage spikes. Controlling the point during any applied half cycle of AC voltage that the trigger pulse is applied to the gate of the SCRs makes it possible to control the output power of the DC power supply.

The signal developed in the power section of the voltage regulator (fig. 19-3), is used as DC control current to the static exciter.

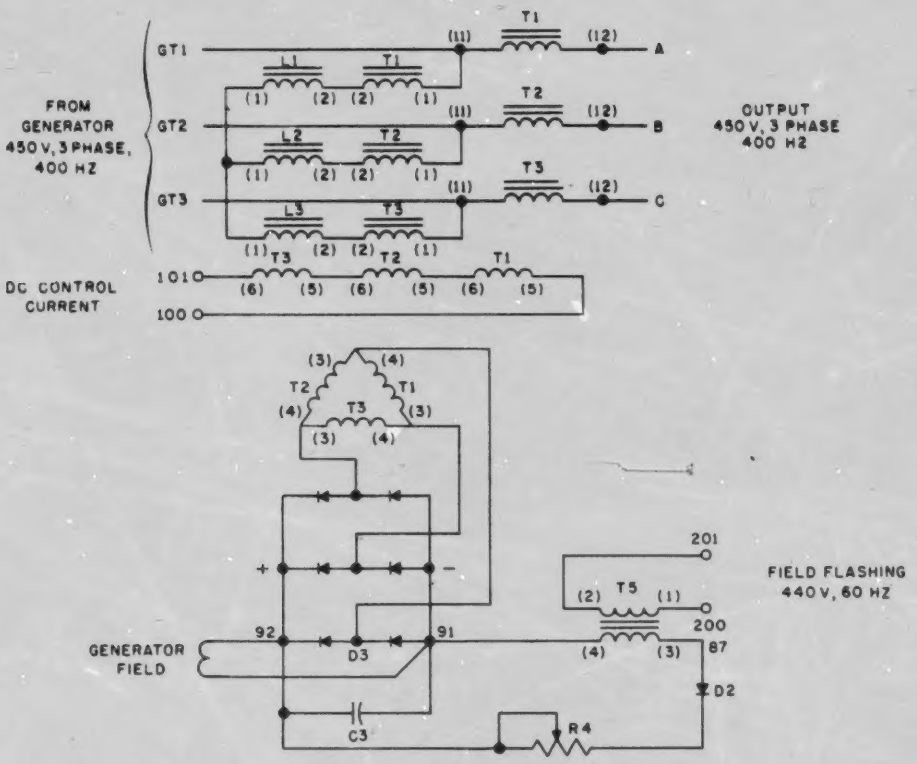
STATIC EXCITER

The static exciter (fig. 19-6) which derives its operating power from the generator output, is


A
TO TRIGGER CONTROL
B
SCR2
SCR 1
AC IN
C
D
D3
D2
D1
SP1
E
DC OUTPUT
F
(a)
AC IN
0
1
2
3
4
(b)
TIME
TRIGGER PULSE
1
2
3
4
(c)
TIME
DC OUTPUT
0
1
2
3
4
(d)
TIME

40.115

Figure 19-5.—Power circuit.


FROM
GENERATOR
450 V, 3 PHASE,
400 HZ
GT1
GT2
GT3
L1
L2
L3
T1
T2
T3
(1)
(2)
(11)
(12)
A
B
C
OUTPUT
450 V, 3 PHASE
400 HZ
DC CONTROL
CURRENT
101
100
(6)
(5)
(3)
(4)
+
−
92
91
D3
GENERATOR
FIELD
C3
R4
201
200
T5
87
D2
FIELD FLASHING
440 V, 60 HZ

40.116

Figure 19-6.—Static exciter.

designed to supply the correct amount of field current to the generator, so as to maintain a constant output voltage for application to a load that varies in magnitude or has a lagging power factor. During the motor starting period there is no generator output and the generator field current is supplied by the field flashing circuit. The field flashing circuit derives its operating power from the 60-cycle supply voltage. This voltage is reduced to 30 volts by transformer T5, rectified by diode D2, and filtered by capacitor C3. The DC current then flows through dropping resistor R4 and excites to the generator field.

The saturable current potential transformer (fig. 19-6) has two sets of primary winding's exciting a common secondary. The primary windings of T1, T2, T3 in series with the load are current primaries. Those primary windings in parallel (T1, T2, T3) are potential primaries. Both primaries acting in conjunction excite the common secondary (3-4 windings of T1, T2, T3) to provide generator field excitation.

When a load is applied to the output, current will flow in the current primaries of T1, T2, and T3 of the saturable current potential transformer. A current transformer action will take place with the common secondary 3 and 4 of T1, T2, and T3 of the saturable current potential transformer which will add to the field excitation current caused in the secondary by voltage primary 1 and 2 of the saturable current potential transformer. This action is explained later. L1, L2, and L3 are chokes.

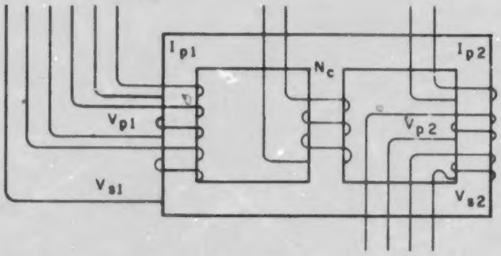
The field excitation current will rise in proportion to the application of load and lagging power factor. Adding a DC control winding on the saturable current-potential transformer will change the coupling between primary and secondary windings, thus this winding can control the generator output voltage. This is accomplished by connecting the output of the voltage regulator to the DC control winding.

The signal developed in the power section of the voltage regulator (fig. 19-3) is used as DC control current to the static exciter.

The use of the saturable current-potential transformer (SCPT) is relatively new to motor generator application. Since the basic operation of each core in the (SCPT) is identical, only one core will be explained.

The basic operation of the saturable current-potential transformer (SCPT) is explained with the aid of figure 19-7. It consists of two voltage primary windings (V_{p1} and V_{p2}), two current primary windings (I_{p1} and I_{p2}), two secondary windings (V_{s1} and V_{s2}) and a DC control winding [illegible]).

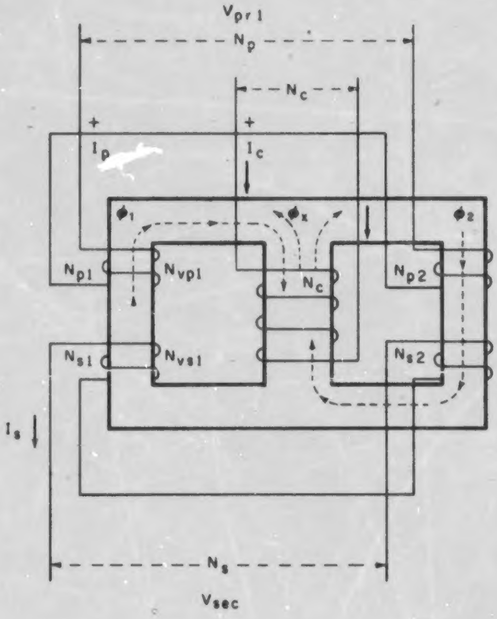
[illegible] figure 19-7, these windings are arranged on a three-legged E type lamination. For simplicity consider the leg of the transformer with windings V_{p1}, I_{p1}, and V_{s1}. The V_{p1} winding and the secondary winding V_{s1} function like a normal power transformer, and the current primary winding (I_{p1}) and secondary winding function like a normal current transformer. When either of the primary windings V_{p1} or I_{p1} induce a voltage into the secondary winding (V_{s1}) (secondary winding is connected to a load) a current will flow in the secondary winding (V_{s1}). The SCPT is constructed in such a manner that the current flow in the secondary is the sum of the current that would be caused to flow by the separate V_{p1} and I_{p1}, windings. As can be seen in figure 19-7 there is a voltage and current primary winding and a secondary winding on each of the cores of the SCPT. The function of each is as described above.



40.117
Figure 19-7.—Saturable current-potential transformer.

To understand the principle of operation of the DC control winding refer to figure 19-8. The action that takes place between the primary winding (either current primary or voltage primary), the secondary winding, and DC control winding is the same. Therefore, only a voltage primary winding (N_p) is shown in figure 19-8.

The outer legs of the core are each wound with a primary and a secondary winding, and on the center leg is wound the control winding. It should be noted that the finishes of the primary and also the secondary windings on each outer leg of the core are joined together, which prevents any net flux change in the center leg so that no fundamental frequency voltage is induced in the control winding. When voltage is applied to the primary windings, a current flows in these windings which is labled I_p in figure 19-8. If the primary voltage is instantaneously positive (+) at the start of winding N_{p1}, then the current



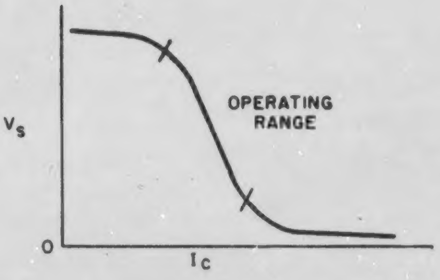
40.118
Figure 19-8.—Saturable potential transformer.

flowing through the turns of N_{p1} and N_p2 should create the flux $\phi 1$ and $\phi 2$. In accordance with the left-hand rule which defines winding polarity.

The flux caused by N_{p1} is in an upward direction and the flux caused by N_{p2} is in downward. These fluxes will close their loop through the center leg of the laminated core because of the shorter path it presents; but because the fluxes are of equal magnitude they cancel each other in the center leg and thus induce no voltage in the control winding (N_C). Because the fluxes $\phi 1$ and $\phi 2$ link the secondary turns N_{s1} and N_{s2}, a voltage is induced in each of these whose sum is V sec. The relationship that exists between the primary and secondary windings when the core is not saturated is identical to any voltage transformer whose core is not saturated. When a direct current flows through the control winding N_C, in the direction shown by I_C a DC flux ϕ_x is created, according to the left-hand rule, which is in an upward direction opposing $\phi 1$ and aiding $\phi 2$. When the magnitude of the DC flux becomes great enough, it begins to force the core material into saturation. Saturation may be defined as the condition in the magnetic material where increase of magnetomotive force causes no increase in flux. The coupling of the primary and secondary voltage is accomplished only when there is a flux change; consequently, when the core material is forced into the condition where no flux change can take place, the coupling of the primary and secondary voltages becomes nonlinear, and effect of decoupling the secondary winding is produced. Figure 19-8 indicates the path of DC flux when the start of N_{p1} is positive. Naturally, when the applied voltage polarity reverses itself the fluxes $\phi 1$ and $\phi 2$ also reverse themselves; but the DC flux through the control winding then forces $\phi 1$ into saturation before $\phi 2$ is forced into saturation. Since the load on the saturable potential transformer secondary is magnetically coupled to the primary of the saturable potential transformer, the variable control current through the winding N_C will produce a variable secondary output voltage. The control current versus the output voltage characteristic of the saturable potential transformer is shown in figure 19-9. The saturable potential transformer is designed to operate in the linear position of the characteristic curve as shown in figure 19-9.

POWER SENSING NETWORK

The power sensing network functions to balance the load between generators operating in parallel. In single generator operation, the power sensing network is not used.



40.119

Figure 19-9.—Characteristic curve of saturable potential transformer.

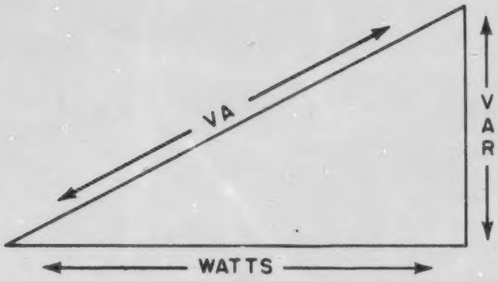
This network is designed to sense real power or the kilowatt (KW) output of the generator only, as opposed to kilovolt amperes (FVA) output.

This generating system has an output rating of 30 KW at 0.8 power factor, 37.5 KVA. The current in each line with this load will be 48.5 amperes at 450 volts. A 30-KW load at unity power factor will result in a current of only 38.5 amperes per line. The difference in the output current with identical kilowatt loads is the result of the flow of reactive current in the load circuit. This is known as the reactive volt ampere component of the load and is abbreviated VAR.

This VAR component of the load is caused by the current of the generator being out of phase with the voltage. The mathematical relationship of power factor, watts, VA, and VAR is shown in figure 19-10.

It is possible for the current to either lead or lag behind the voltage, and, if it is lagging (for inductive reactive loads), the power factor would be a lagging power factor.

The phase angle of the current in relation to the voltage of the generator output in combination with the magnitude of the output current is used by the power sensing network to produce an output signal that will vary in magnitude in relation to the useful output (KW) of the generator, and will produce no output when the generator load is entirely VAR. Any combination of VAR and KW will produce an output signal that is directly proportional to the KW load only.



$$\text{POWER FACTOR} = \frac{\text{KW}}{\text{KVA}}$$

$$\text{VA} = \sqrt{\text{WATTS}^2 + \text{VAR}^2}$$

$$\text{WATTS} = \sqrt{\text{VA}^2 - \text{VAR}^2}$$

$$\text{VAR} = \sqrt{\text{VA}^2 - \text{WATTS}^2}$$

40.120
Figure 19-10.—Watt, VA, and VAR relationship.

The amount of power required by the motor to drive the generator is also directly proportional to the KW output of the generator. This makes it possible to use the output signal of the power sensing network with changing load.

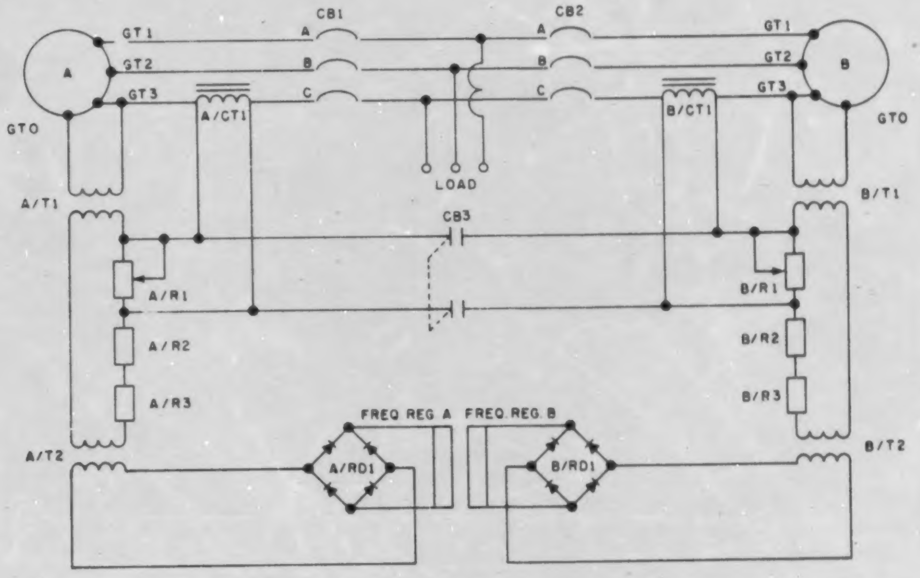
A power sensing network has been provided in one phase of the generator output (fig. 19-11). For simplicity, consider first the power sensing circuit of generator (A). This circuit consists of current transformer A/CT1 and real power-sensing rheostat A/R1. Note that the power transformer A/T1 is connected from neutral to line C, and, therefore, the voltage across the primary of transformer A/T1 will be in phase with the current in line C at unity power factor. Transformer A/T2, which is the frequency sensing transformer, is in parallel with the power transformer A/T1, and, therefore, the voltage output of the secondary of transformer A/T2 is in phase with the voltage in the primary of transformer A/T1. Then at unity power factor, the voltage across the secondary windings A/T2 will be in phase with the current in line C. Real power sensing rheostat A/R1 is actually the load resistor for current transformer A/CT1. Therefore, when a load is applied to the output of generator (A), a voltage will be impressed across rheostat A/R1 and this voltage will be in phase with the voltage across the secondary winding of transformer A/T1. The voltage from transformer A/T2 and the voltage across resistor A/R1 will add, and the sensed voltage will be an increased voltage to rectifier A/RD1. This would represent an increased output frequency, thus, the regulator would decrease the speed of the motor and thus reduce the output frequency of the generator. This is known as a frequency droop. To eliminate this droop in singular operation, a shorting bar or relay contact is placed across rheostat A/R1 thus disabling the power sensing system. If the leads from the current transformer A/CT1 to resistor A/R1 are reversed, the phase relationship of the voltage across resistor A/R1 would be 180° out of phase with the secondary of transformer A/T1. Therefore, with increasing load the regulator would try to raise the output frequency of the generator. This is know as frequency compounding.

PARALLEL OPERATION

Refer to figure 19-11 and note that the generator (B) has a real power sensing system exactly as generator (A). Note also that not only is current transformer A/CT1 connected across its load rheostat A/R1, but when circuit breaker CB3 is closed, it is also connected across real power sensing rheostat B/R1. Consider what would happen if generator A were to supply the greater amount of real power to the load. There would be a difference in potential between current transformers A/CT1 and B/CT1. Due to the difference in potential, a current will flow in resistors A/R1 and B/R1 connected in parallel. The current will be in phase with the voltage out of secondary of transformer A/T1 and 180° out of phase with the secondary voltage of transformer B/T1. Hence, the regulator of generator (A) will decrease its output frequency and the regulator of generator (B) will raise its output frequency. This will permit the generator to operate in parallel without speed droop with changing load and to divide the load (KW) evenly between them.

SAFETY

The inherent dangers of rotating machinery are kept to a minimum, however it remains the responsibility of supervisory personnel to ensure that men performing preventive and corrective maintenance are thoroughly acquainted with the possible hazards involved. Except during supervised maintenance, all doors and covers should



40.121

Figure 19-11.—Power sensing.

be in place. Since considerable semiconductor application is made here, test equipment settings and proper soldering techniques must be observed when maintenance is required.

MAINTENANCE

The 3-M system of maintenance provides adequately for preventive maintenance on this motor generator. NO corrective maintenance should be attempted without a thorough under-standing of the pertinent sections of the manufacturer's technical manual. Troubleshooting charts are of great value when employed with test procedures in identification and isolation or problem areas.

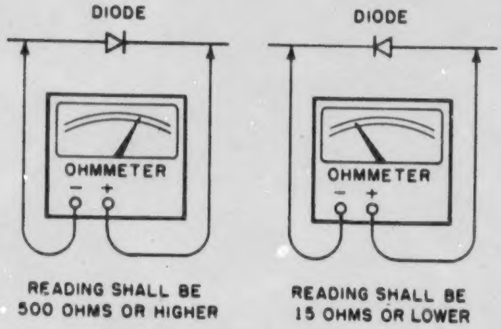
One test that may be of some assistance is that used for silicon diodes. With this test, they may be tested without removal from the circuit by the use of a low range (0-500 ohms) ohmmeter. The test is performed by readings taken with the ohmmeter leads connected across the diode in the opposite or reverse direction. This means that the positive lead of the ohmmeter will be connected to first one side of the diode and then to the opposite side. Comparison of the reading will indicate the condition of the diode. When the positive lead is connected to the anode side of the diode and the negative lead is connected to the cathode side, the ohmmeter will indicate a low value (15 ohms or less). With the ohmmeter leads reversed across the diode, a higher reading will be obtained. Refer to figure 19-12. A front to back ratio of 10 to 1 is usually considered a good diode.

Various test setups have been devised for transistors and often these are included in the manufacturer's technical manual.

A key to good maintenance which should be stressed is familiarity with the manufacturer's technical manual.

STATIC INVERTER

The need for a highly dependable static (no moving parts) source of 400-hertz power lead is the development of the 4345A static inverter. At present the system is employed in SINS installations, however, most of the circuits employed receive wide use throughout IC installations.



40.122
Figure 19-12.—Diode test.

The model 4345A Static Inverter delivers a closely regulated source of 400 hertz 3-phase power from a nominal 250 VDC source. Two single-phase static inverters are operated with a controlled 90° phase difference. Pulse width modulation is used for control of the output voltage of each static inverter. The outputs of the two inverters are fed into two scott (T) connected transformers to provide a three-phase output from a 2-phase input.

The components are enclosed in an aluminum cabinet (fig. 19-13). The meter panel assembly (1) contains the instruments and controls necessary for the operation of the equipment. The inverter module (2) contains a control circuit+ 30 VDC power supply, a drive circuit + 30 VDC power supply, and input sensing and step change adjustment circuit, a synchronizing subassembly, three variable pulse width generators, a frequency standard oscillator, two driver subassemblies, and two silicon control rectifier power stages. The power stage (3) contains the capacitors, transformers, and filters associated with the power stages of the inverter.

FUNCTIONAL DESCRIPTION

A simplified functional block diagram of the model 4345A static inverter is shown in figure 19-14. A brief discussion of the various components and circuits contained in the unit follows.

Oscillator Assembly

The oscillator (fig. 19-14) consists of a 1600-Hz tuning fork controlled oscillator and a binary frequency divider (countdown) circuit. The countdown circuit reduces the 1600-Hz oscillator frequency to an 800-Hz reference frequency required by the inverter control circuits.

Variable Pulse Width Generators

The inverter module contains one variable pulse width generator (VPWG) for each inverter (main and secondary VPWG, fig. 19-14), and one VPWG for controlling the phase angle between the inverters. Each VPWG contains a monostable (one-shot—multivibrator, a modulator circuit, and an inverter output voltage error sensing circuit.)

The modulator circuit consists of a transistor and resistors connected in the discharge path of a capacitor. Varying the level of conduction of the transistor varies the discharge time of the capacitor which varies the time the monostable multivibrator remains in the unstable state. The time the monostable multivibrator remains in the unstable state determines the width of the output pulse.

The monostable multivibrator used in the VPWG can be triggered only on positive pulses.

The output voltage error-sensing circuit for each VPWG receives an AC signal (via the feedback loop), proportional to the output voltage of the inverter. The AC signal is converted into a corresponding DC signal, compared with a reference signal and the error (difference) signal is used to control the level of conduction of the transistor in the modulating circuit.

The secondary VPWG regulates the output voltage of phase AB, and the phase control and main VPWG regulate the voltages of phases BC and CA respectively. The phase control VPWG also provides a delay in time between triggering of the main and secondary VPWG to control the phase angle between power stages (1 and 2) of the inverters.

The main and secondary VPWGs deliver one 800 Hz input to each of the driver stages (1 and 2), and another 800-Hz input to a binary countdown circuit which in turn delivers two 400-Hz inputs 180° apart to each of the driver stages.

Drivers

Each driver contains four drives pulse generators. Two of the drive pulse generators generate the triggers for the power SCRs ("turn on" SCRs), and the other two generate the triggers for the commutating SCRs ("turn off" SCRs), in the power stages.

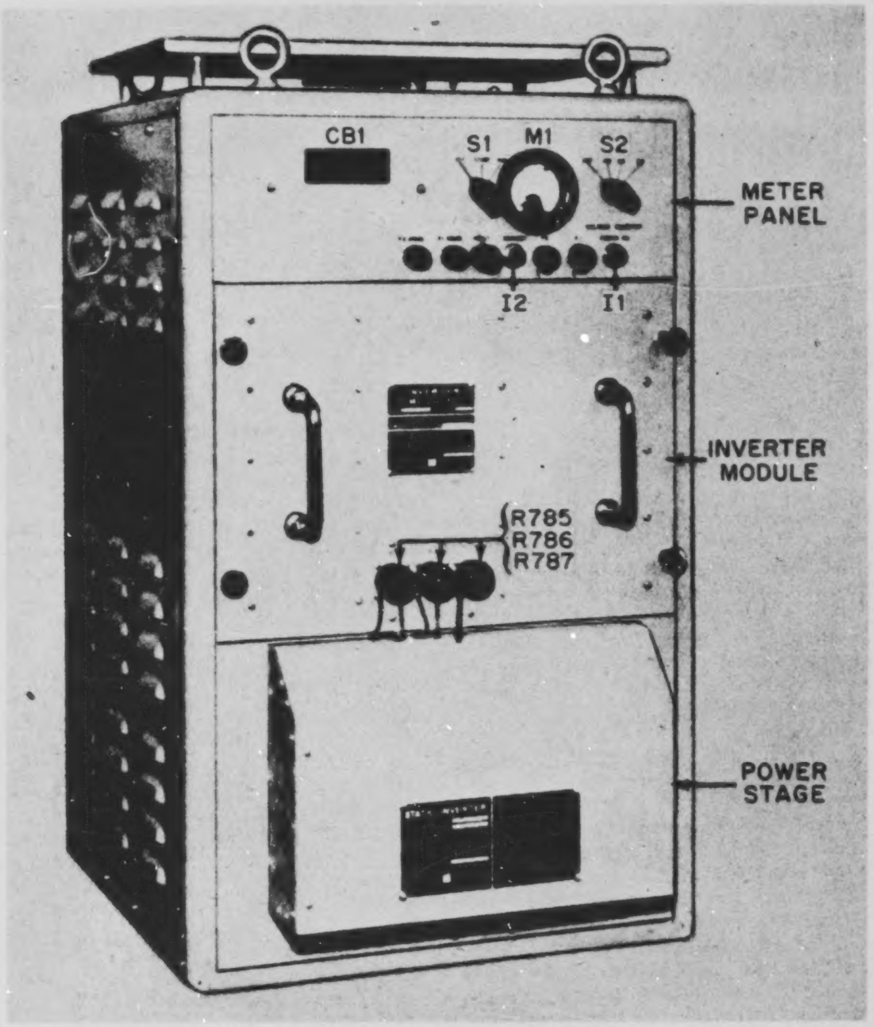


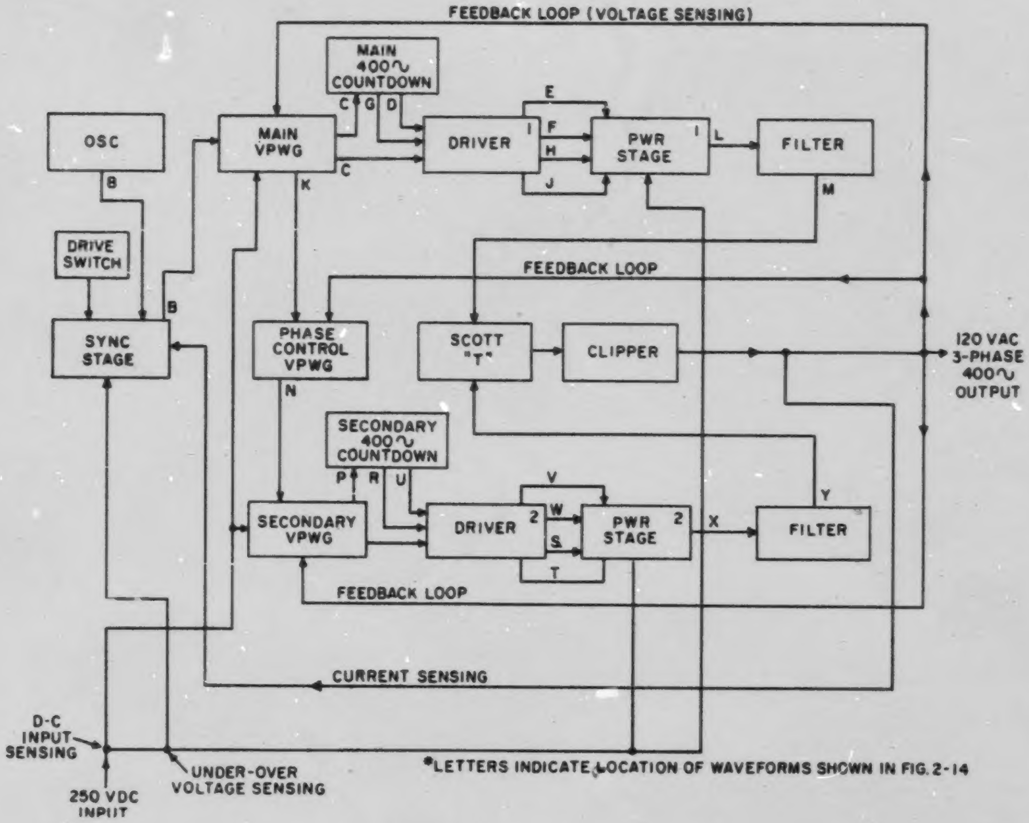
Figure 19-13.—Static inverter. 40.79

A unijunction transistor is utilized to generate the drive pulse trigger.

Power Stages

Each power stage contains three power and three commutating SCRs for each side of the power stage, and a transformer. The SCRs switch the DC source across the primary of the transformer at a 400 Hz rate to produce a 400 Hz square wave output. The square wave output is filtered to produce a sine wave.

The SCR is the semi-conductor equivalent of the gas thyratron tube. Once it is made to conduct it will continue to conduct for the remaining positive half cycle (anode positive with respect to cathode). Neither the removal of the gate voltage, nor the reversal of the gate voltage will stop the SCR from conducting. Conduction may be stopped only by removing the positive anode to negative cathode voltage completely, or by applying a slightly greater reverse negative anode to positive cathode voltage.

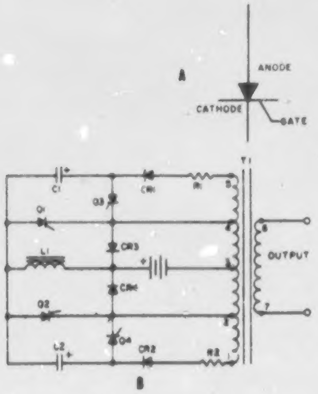

FEEDBACK LOOP (VOLTAGE SENSING)
MAIN 400∿ COUNTDOWN
C G D
E
OSC
MAIN VPWG
DRIVER 1
F
H
J
PWR STAGE 1
L
FILTER
B
C
K
M
DRIVE SWITCH
FEEDBACK LOOP
B
SYNC STAGE
PHASE CONTROL VPWG
SCOTT "T"
CLIPPER
120 VAC 3-PHASE 400∿ OUTPUT
N
SECONDARY 400∿ COUNTDOWN
P R U
V
Y
SECONDARY VPWG
DRIVER 2
W
S
T
PWR STAGE 2
X
FILTER
FEEDBACK LOOP
CURRENT SENSING
D-C INPUT SENSING
250 VDC INPUT
UNDER-OVER VOLTAGE SENSING
•LETTERS INDICATE LOCATION OF WAVEFORMS SHOWN IN FIG. 2-14

40.80

Figure 19-14.—Simplified block diagram of static inverter.

The principle of operation of the power stages can be described by referring to the simplified schematic diagram (fig. 19-15). When power SCR (Q1) is triggered on by an output pulse from the driver, a rising current will flow through primary winding 3-4 of output transformer T1 (through Q1, L1, and the battery), inducing a voltage in the secondary 6-7 in one direction. By autotransformer action, a voltage is also induced in winding 4-5. This voltage charges capacitor C1 through Q1, CR1, and R1. When commutating SCR (Q3) is triggered on by the driver, the positive voltage from the right plate of C1 is applied through Q3, (Q3 conducting) to the Q3-CR3 junction. This applies a reverse negative anode to positive cathode voltage to Q1 causing Q1 to stop conducting. Capacitor C1 discharges through L1, CR3, and Q3. With Q1 off, the current in winding 3-4 of T1 gradually drops to zero, and slightly later when the 3-4 current ceases the voltage between secondary terminals 6-7 drops to zero. The voltage between terminals 4-5 also drops to zero. When C1 discharges to zero Q3 stops conducting. Because of the gradual drop of current in the 3-4 winding the voltage induced in the 6-7 winding is of reversed polarity and low amplitude.

On the other side of the power stage, power SCR (Q2) is then triggered on by the driver output and capacitor C2 charges in the same



40.81
Figure 19-15.—Power stage, simplified schematic diagram.

manner as C1 charged. The operation of this side of the power stage is the same as for the side just discussed. The polarity of the output is reversed, however, which completes the square wave output on the secondary of T1.

Filters

The filters (fig. 19-14) convert the square wave outputs of power stages 1 and 2 to sine waves. Each filter consists of one series and four shunt LC filters. The series filter provides a low impedance path for the 400-Hz fundamental frequency, and a high impedance path for the odd harmonics in the output. The predominate odd harmonics are filtered out by individual shunt filters. A shunt filter is provided for the third, fifth, seventh, and ninth harmonic. Even harmonics are negligible due to the balanced design of the push-pull power stage.

Scott "T" Transformer

The Scott "T" transformer is a center-tapped autotransformer. The output voltages from the main and secondary inverter filters combine in the Scott "T" transformer to produce a 120 volt, 3-phase output.

Clipper

The 3-phase clipper network consisting of capacitors, resistors, and diodes is connected across the 3-phase output of the Scott "T" transformer. The clipper network functions to reduce voltage transients in the inverter 3-phase output.

Synchronizing Stage

The SYNC stage (fig. 19-14) contains an emitter-coupled binary circuit and a bistabel multivibrator. This stage ensures that drive pulses are initiated properly when the unit is turned on. If the drive switch is turned on at the wrong time with respect to the reference signal from the oscillator, operation is delayed until the beginning of a cycle in the reference signal.

The binary circuit in the SYNC stage has three interlock circuits which control the switching of the bistable multivibrator (the "turn on" and "turn off" condition of the inverter). The three interlock signals are provided by the drive switch, the under-over voltage sensing circuit, and the overload-sensing circuit. A positive signal of 20 VDC or greater from either of these three sources will cause the binary circuit to switch, which in turn will cause the bistable multivibrator to switch to the "turn off" condition on the inverter.

The SYNC stage also contains a delayed B-voltage interlock to ensure that the oscillator, VPWG, and synchronizing circuits have sufficient time to stabilize before the inverter is turned on. A unijunction circuit provides a time delay of approximately two seconds after the inverter main power circuit breaker is turned on, before the control circuit + 30 VDC is applied to the inverter circuits.

Drive Switch

The drive switch (S1, fig. 19-13) has three positions: OFF, START, and RUN. In the OFF position (with the main power circuit breaker ON), power is supplied to the standby indicator light to indicate that the inverter is in the standby mode, and a + 30 VDC signal is supplied to the synchronizing stage. The drive switch also functions in the OFF position to connect the input DC voltage as a source of power for the control circuit + 30 VDC power supply.

In the START position power is removed from the indicator light, and the + 30 VDC signal to the synchronizing stage is removed allowing signals to pass to properly start the inverter.

When the drive switch is switched to the RUN position, the input DC voltage for the control circuit + 30 VDC power supply is disconnected and a bridge rectified output from phase CA of the inverter is used.

Power Supplies

The power supplies in the inverter are the control circuit + 30 VDC power supply and the drive circuit + 30 VDC power supply. The control circuit + 30 VDC power supply provides power for all control circuits except the drivers and under-over voltage circuits. This power is obtained from the input DC source during the START mode and from phase CA of the inverter output during the RUN mode as mentioned previously.

The drive circuit + 30 VDC power supply provides power for the drivers and the under-over voltage circuits. This power is obtained from the inverter input DC voltage.

Overload Circuit

The overload circuit functions to turn the inverter off in case of overload. An overload current from the current sensing circuit produces a DC signal of sufficient amplitude to trigger a unijunction circuit which in turn triggers a bistable multivibrator. The bistable multivibrator output is fed to the binary circuit in the SYNC stage which switches the bistable multivibrator in this stage putting the inverter in the "turn off" condition.

Under-Over Voltage-Sensing Circuit

The under-over voltage-sensing circuit functions to turn the inverter off when the input DC source voltage is out of the operating range (210-355VDC) of the inverter.

A modified Schmitt trigger circuit is used to supply the interlock signal to the binary circuit in the SYNC stage. The Schmitt trigger is a form of bistable multivibrator. It differs from the conventional bistable multivibrator however, in that it is at all times sensitive to the amplitude of the input signal. If the amplitude of the input signal is above a specified level, the Schmitt trigger bistable multivibrator will be in one state (one transistor conducting while the other is off); if the amplitude is below a specified level it will be in the other state.

DC Input Sensing

The DC input sensing circuit functions to compensate for changes (step changes) in the input DC voltage source. A voltage-sensing network composed of resistors and capacitors is connected to the bus that supplies the DC input to the inverter. Positive and negative step changes in the DC supply voltage produces positive and negative pulse outputs from the voltage-sensing network. The output pulses are fed to the pulse width modulator circuit in the main and secondary VPWGs to compensate for the voltage change.

OPERATION CYCLE

When the main power circuit breaker is on and the drive switch is in the OFF position, the inverter is in the standby mode of operation. The standby mode is composed of a transient and a steady state condition. The transient condition lasts for approximately two seconds. This 2-second time delay is provided by the delayed B+ voltage interlock to allow the inverter circuits to reach a steady state as mentioned previously.

During the standby mode the 800-hertz countdown circuit of the oscillator supplies an 800-Hz square-wave voltage to the SYNC stage and the main VPWG, (waveform B fig. 19-16A and fig. 19-14). A + 30 VDC signal is applied to the binary circuit in the SYNC stage via the drive switch (S1 fig. 19-13) which keeps the bistable multivibrator in the SYNC stage in the "turn off" state.

Turning the drive switch to the START position removes the 30 VDC signal from the binary circuit and allows the first negative-going edge of the 800 Hz square wave (waveform B) to reverse the bistable multivibrator in the SYNC stage. This allows the positive-going edge of waveform B (at time 0 fig. 19-16A) to trigger the monostable multivibrator in the main VPWG, (fig. 19-14).

The trailing edge of the first positive half of waveform C (edge No. 1, fig. 19-16A), from the main VPWG triggers the main 400-hertz countdown circuit. The main 400-hertz countdown output (D) triggers the pulse generator in the driver which generates the pulse (E) to trigger the power SCRs for one side of the power stage. The main 400 hertz countdown (D) and the leading edge of the second positive half of waveform C (2, fig. 19-16A) provide coincident gating for the pulse generator in the driver that generates the pulse (F) to trigger the commutating SCRs in this side of the power stage.

The main 400-hertz countdown output (G) triggers the pulse generator in the driver which generates the pulse (H) to trigger the power SCRs in the other half of the power stage. Waveform G and the leading edge of the next positive half of waveform C (3, fig. 19-16A) gate the pulse generator in the drive that generates the pulse (J) to trigger the commutating SCRs in this half of the power stage. The leading edge of waveform C controls the duration of the ON time of the power stage.

The leading edge of the 180° signal (K) from the main VPWG triggers the phase control VPWG. The phase control VPWG provides a delay in time (N) between the main and secondary VPWGs to control the phase angle between the two power stages.

The secondary VPWG is triggered by the trailing edge of the phase control VPWG signal (waveform N fig. 19-16B). The trailing edge of wave P from the secondary VPWG triggers the secondary 400 hertz countdown. The outputs from the secondary 400 hertz countdown (U and R) and the leading edge of the secondary VPWG output (P) trigger the pulse generators in the secondary driver in the same manner as just described for the main driver. The sequence of operation for the secondary power stage is the same as for the main power stage.

OPERATING PROCEDURE

To operate the static inverter, turn the main power circuit breaker CB1 (fig. 19-13) to ON. Turn the drive switch, S1, to the OFF position. The standby light 12 should light. Turn the drive switch S1, to the START position. The power on light, I1, should light, and the standby light, I2, should go out. After the output of the inverter has reached a steady state (approximately 2 seconds), turn the drive switch, S1, to the RUN position. Adjust the voltage adjust potentionmeters, R785, R786, and R787, to the required output for each phase. Use the voltage selector switch S2, and meter M1, to read the voltage of each phase. The output voltages must be adjusted in the following sequence; phase CA, phase AB, then phase BC.

To secure the inverter turn the drive switch, S1, to the OFF position, then turn the power circuit breaker CB1 to OFF.

MAINTENANCE

Maintenance of the static inverter should normally be limited to simple replacement with a new or serviceable module. This will ensure rapid restoration of the inverter into service, without risking dangers of handling high test voltages.

Complete familiarization with the theory of operation must be obtained before troubleshooting is attempted. Then follow the step-by-step procedures outlined in the manufacturer's technical manual while using the specified test equipments.

RECTIFIER POWER SUPPLY

FUNCTIONAL DESCRIPTION

The Bogue Model 432OB, Automatic Direct Current Power Supply with an accuracy of ± 5% ripple 5% for a voltage change of ±10% and frequency change of ± 5% is an example of the units currently being extensively used throughout the fleet. This unit employing a controlled saturable core reactor takes a 450 VAC, 3-phase, 60 hertz, 15 amp, .65 PF, 7.5 KW input and converts it into 50 VDC 5.0 KW output. The major components and the adjusting rheostat are shown in their drip-proof housing in figure 19-17.

OPERATION

To achieve an automatic supply of DC (fig. 19-18), the unit utilizes a magnetic amplifier controlled saturable core reactor. One such saturable core is shown in each phase of the 3-phase supply (LI ABC) and is connected to a 3-phase transformer (TI). The transformer output in turn supplies a reduced and regulated voltage to the output rectifiers (CR1 A, B, C) which employ capacitors (C1, A, B, C, D) and resistors (R7 A and B) to reduce ripple to a minimum.

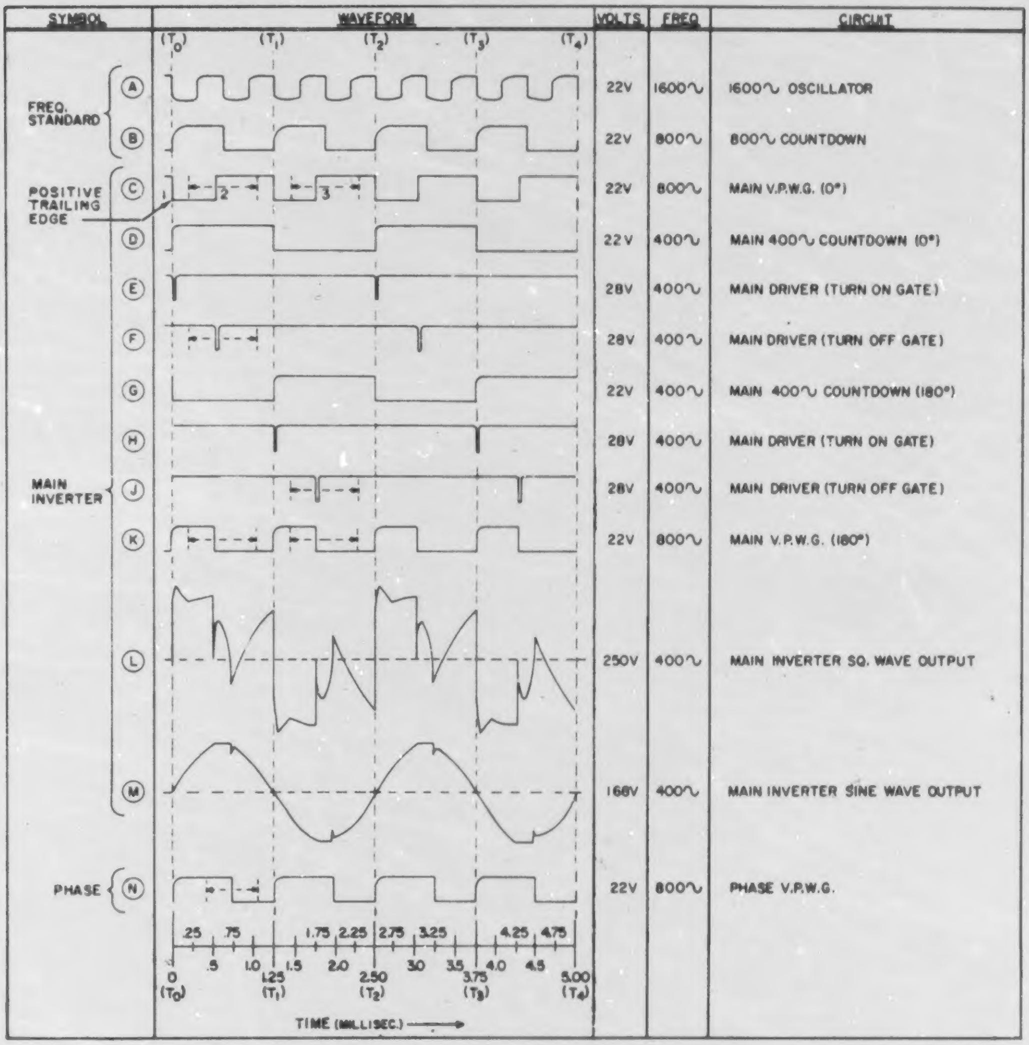
The preamplifier is a self-saturated 3-phase magnetic amplifier (L2), which compares the output voltage of the unit (terminals 11 and 12 of L2) to a reference derived from the input line (terminals 13 and 14 of L2) and uses the error derived (terminals 9 and 10 of L2) to adjust the saturation level of the saturable core reactor (L).

The change is such that a change in output voltage is in the direction as to reduce error to a minimum.

Component R5 is an internal dropping resistor, while R6 is the voltage adjusting rheostat on the unit face. R1 A and B are feedback resistors in the L1 circuit as is R8 in the L2 circuit. R2 adjusts preamp gain.

SAFETY

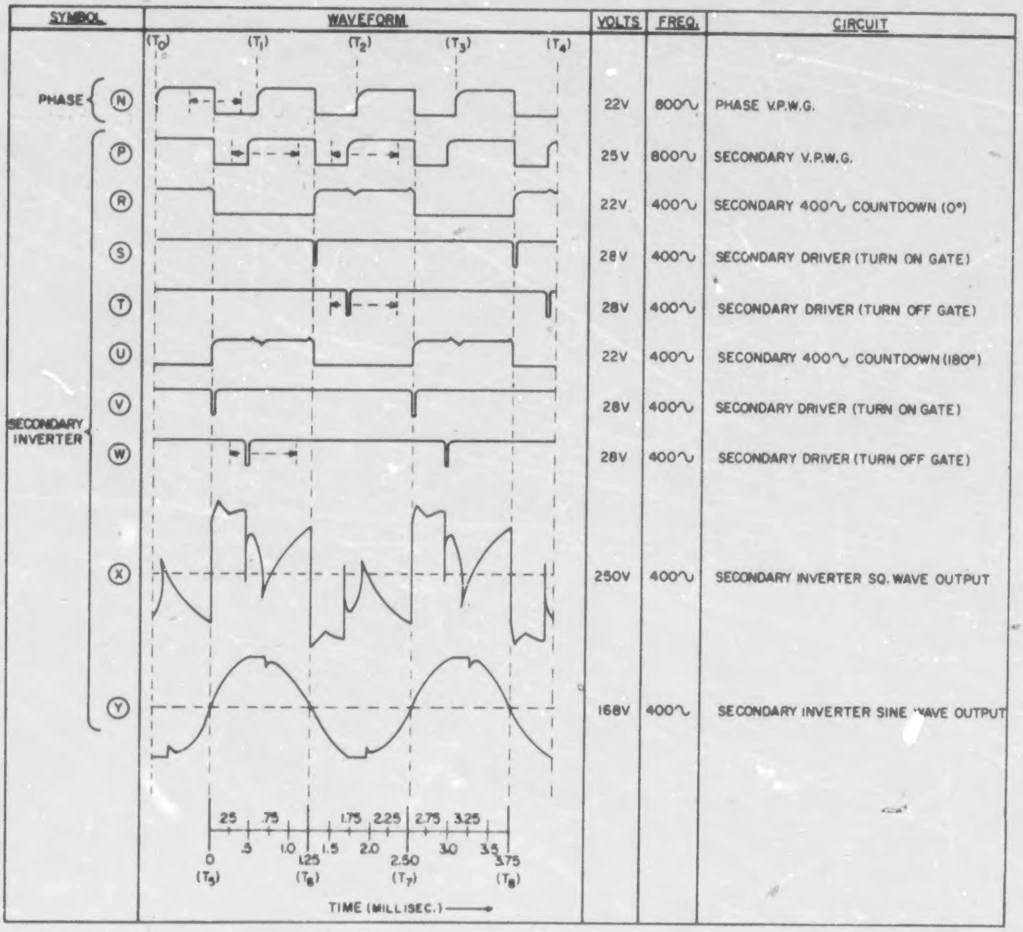
The manufacturer is specific in mentioning the inherent fatal voltages in the unit and advising maintenance only with power off. He also


SYMBOL
WAVEFORM
VOLTS
FREQ
CIRCUIT
(T0) (T1) (T2) (T3) (T4)
FREQ. STANDARD
A 22V 1600∿ 1600∿ OSCILLATOR
B 22V 800∿ 800∿ COUNTDOWN
POSITIVE TRAILING EDGE
C 22V 800∿ MAIN V.P.W.G. (0°)
D 22V 400∿ MAIN 400∿ COUNTDOWN (0°)
E 28V 400∿ MAIN DRIVER (TURN ON GATE)
F 28V 400∿ MAIN DRIVER (TURN OFF GATE)
G 22V 400∿ MAIN 400∿ COUNTDOWN (180°)
H 28V 400∿ MAIN DRIVER (TURN ON GATE)
MAIN INVERTER
J 28V 400∿ MAIN DRIVER (TURN OFF GATE)
K 22V 800∿ MAIN V.P.W.G. (180°)
L 250V 400∿ MAIN INVERTER SQ. WAVE OUTPUT
M 168V 400∿ MAIN INVERTER SINE WAVE OUTPUT
PHASE
N 22V 800∿ PHASE V.P.W.G.
1 2 3
.25 .75 1.75 2.25 2.75 3.25 4.25 4.75
0 .5 1.0 1.25 1.5 2.0 2.50 3.0 3.5 3.75 4.0 4.5 5.00
(T0) (T1) (T2) (T3) (T4)
TIME (MILLISEC.)

A

40.82.1

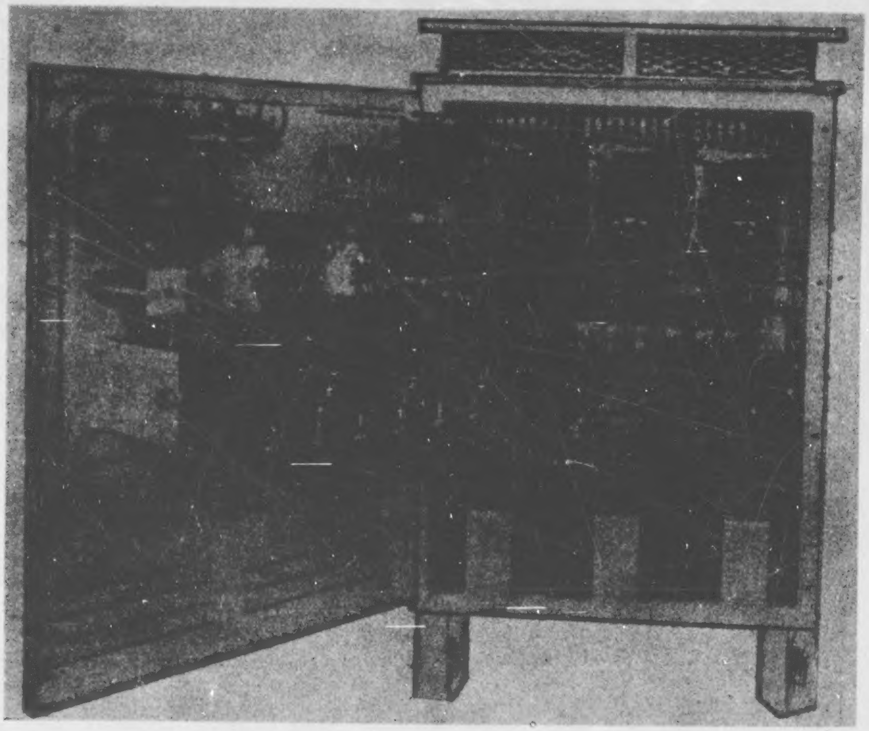
Figure 19-16.—Waveforms.


SYMBOL
WAVEFORM
VOLTS
FREQ.
CIRCUIT
(T0)
(T1)
(T2)
(T3)
(T4)
PHASE
N
22V
800∿
PHASE V.P.W.G.
SECONDARY INVERTER
P
25V
800∿
SECONDARY V.P.W.G.
R
22V
400∿
SECONDARY 400∿ COUNTDOWN (0°)
S
28V
400∿
SECONDARY DRIVER (TURN ON GATE)
T
28V
400∿
SECONDARY DRIVER (TURN OFF GATE)
U
22V
400∿
SECONDARY 400∿ COUNTDOWN (180°)
V
28V
400∿
SECONDARY DRIVER (TURN ON GATE)
W
28V
400∿
SECONDARY DRIVER (TURN OFF GATE)
X
250V
400∿
SECONDARY INVERTER SQ. WAVE OUTPUT
Y
168V
400∿
SECONDARY INVERTER SINE WAVE OUTPUT
.25
.75
1.75
2.25
2.75
3.25
0
.5
1.0
1.25
1.5
2.0
2.50
3.0
3.5
3.75
(T5)
(T6)
(T7)
(T8)
TIME (MILLISEC.)

B

Figure 19-16.—Waveforms—Continued.

40.82.2



40.123

Figure 19-17.—DC power supply.

recommends that the door remain closed, and that when hot maintenance is required, one hand be used.

MAINTENANCE

Since the unit is static, the major problem is cleaning, which can be done with reduced low pressure air. The magnetic amplifier windings, transformers, and all other components readily lend themselves to checkage against manufacturers' technical manual values with an ohmmeter.

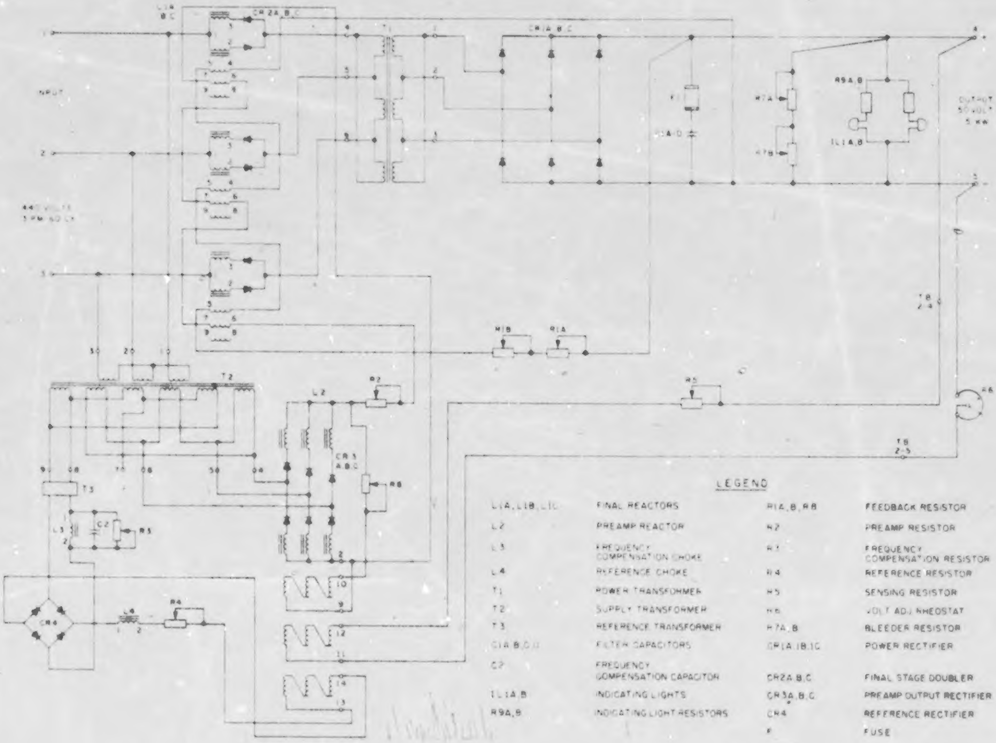
NO-BREAK POWER SUPPLIES

A no-break power supply is designed to provide uninterrupted electrical power to loads by automatic takeover of the power supply should the normal supply fail or momentarily deteriorate beyond the system demands. No-break power supplies are provided for communication systems, computers, navigational equipment, automated propulsion systems and related equipment where even a momentary loss of power would cause a permanent loss of information resulting in the need to recycle or reprogram the equipment. Since equipment requiring no-break power normally requires closely regulated power, no-break power supplies are designed to not only provide uninterrupted power, but also to provide power that is regulated to meet the needs of the equipment it serves.

COMPONENTS

The no-break uninterrupted power supply system consists of two major assemblies plus the storage batteries. The control cabinet and motor-generator set are illustrated in figure 19-19.

The control cabinet contains all the control and monitoring equipments. The motor-generator is a single-shaft unit. Either section of the


LEGEND
L1A, L1B, L1C FINAL REACTORS
L2 PREAMP REACTOR
L3 FREQUENCY COMPENSATION CHOKE
L4 REFERENCE CHOKE
T1 POWER TRANSFORMER
T2 SUPPLY TRANSFORMER
T3 REFERENCE TRANSFORMER
C1A,B,C,D FILTER CAPACITORS
C2 FREQUENCY COMPENSATION CAPACITOR
1L1A,B INDICATING LIGHTS
R9A,B INDICATING LIGHT RESISTORS
R1A,B, R8 FEEDBACK RESISTOR
R2 PREAMP RESISTOR
R3 FREQUENCY COMPENSATION RESISTOR
R4 REFERENCE RESISTOR
R5 SENSING RESISTOR
R6 VOLT ADJ RHEOSTAT
R7A,B BLEEDER RESISTOR
CR1A,1B,1C POWER RECTIFIER
CR2A,B,C FINAL STAGE DOUBLER
CR3A,B,C PREAMP OUTPUT RECTIFIER
CR4 REFFRENCE RECTIFIER
F FUSE
INPUT
OUTPUT

40.124

Figure 19-18.—Schematic diagram of power supply.

motor-generator can perform as the motor with the other as the generator. This permits two operational modes; NORMAL and STOP GAP.

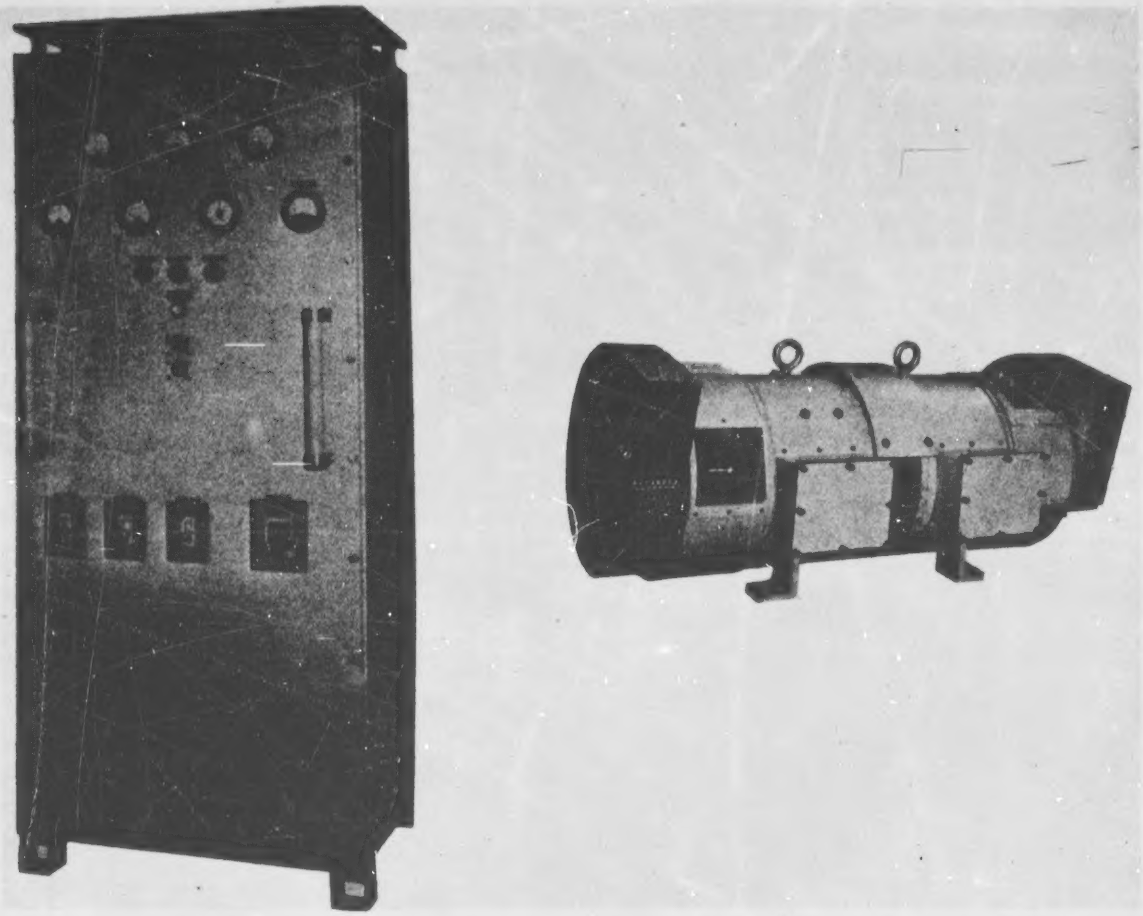
NORMAL operation uses the normal supply (ships generators) and the motor-generator is driven by the a.c. motor from the ships supply and the d.c. generator charging batteries.

In STOP GAP operation the motor-generator is driven by the d.c. motor, with power from the batteries. Under this condition the a.c. generator provides the critical load requirements.

OPERATION

Normal ship's power, as shown in figure 19-20, is applied to the voltage and frequency monitors. If the monitors sense the normal power to be within the frequency and voltage limits required, relay action (relay #1) will allow the normal power to be applied to the load and other circuitry. (It should be noted that the relay numbers in figure 19-20 refer to relay action sequence rather than relay designations.) Power is applied to the relay control power circuit from the battery.

When the system is turned on the motor-generator will accelerate to approximately synchronous speed as an induction motor before a time delay relay is energized. When the delay energizes. (relay #2) it applies normal power to the a.c. field rectifier, via the a.c. voltage regulator, for application as field excitation to the a.c. motor to allow synchronous motor operation. At the same time the d.c. generator is rerouted to the d.c. supply (relay #3) to prevent starting the motor-generator set on d.c. and to charge the



111.142

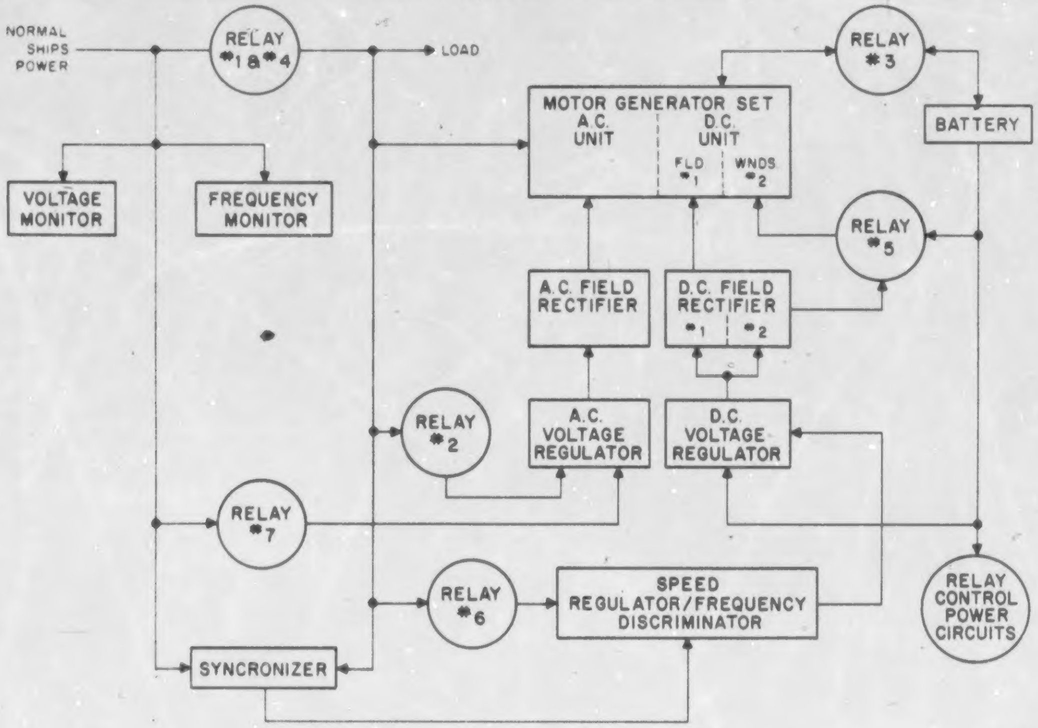
Figure 19-19.—No break uninterrupted power supply system components.

batteries. The system is now operating in NORMAL mode.

If the normal supply falls out of its limits in either voltage or frequency, the respective monitor will sense it and relay action (relay #4) will shut down the motor-generator set. At the same time the d.c. generator field is disconnected from the d.c. field rectifier #2 and connected directly to the battery supply (relay #5). The d.c. motor speed regulator and the a.c. generator voltage regulator are energized (relay #6 and #7) to maintain the required motor speed and control the load voltage. The system is now in the STOP GAP mode.

If the reason for switching modes had been a voltage drop, the voltage would not have dropped below 317 volts and the transition would have been accomplished within one second. In the case of a frequency drop, the change is made within two seconds and the frequency does not drop velow 54 Hz.

When the ships power returns to the specified limits (discussed later), the synchronizer will have the normal power at one side and the a.c. generator power at the other. It will automatically adjust the speed regulator to match the generator frequency to the normal power. The matching is accomplished in less than one minute


NORMAL SHIPS POWER
RELAY #1 & #4
LOAD
RELAY #3
MOTOR GENERATOR SET
A.C. UNIT
D.C. UNIT
FLD #1
WNDS #2
BATTERY
VOLTAGE MONITOR
FREQUENCY MONITOR
RELAY #5
A.C. FIELD RECTIFIER
D.C. FIELD RECTIFIER
#1
#2
RELAY #2
A.C. VOLTAGE REGULATOR
D.C. VOLTAGE REGULATOR
RELAY #7
RELAY #6
SPEED REGULATOR/FREQUENCY DISCRIMINATOR
RELAY CONTROL POWER CIRCUITS
SYNCRONIZER

111.143

Figure 19-20.—No break uninterrupted power supply system block diagram.

and the system is transferred back to a.c. motor drive and battery charge (NORMAL mode).

MONITOR CIRCUITS

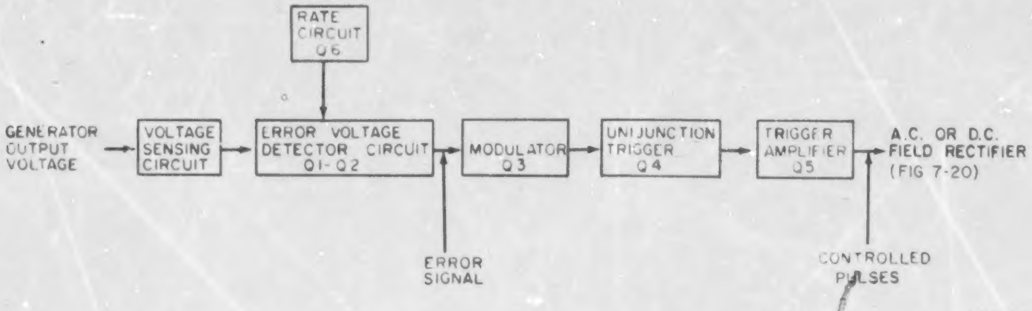
The frequency and voltage monitoring circuits are designed to switch and set from NORMAL to STOP GAP when the input frequency drops below 56 Hz or the input voltage falls below at adjustable limit (330 to 380 volts).

The voltage monitor circuitry is basically the same as the voltage sensing and error voltage detector circuit of the voltage regulator and the frequency monitor is basically the same as the frequency discriminator and error voltage detector circuits. These circuits will be discussed later in this chapter. The big difference in the circuits is the output application. The output of the monitors is used for relay switching, whereas the other circuits output is for regulation of either voltage or frequency.

VOLTAGE REGULATOR

The function of the voltage regulator is to maintain the output voltage at the preset value (± 2%) regardless of temperature or load variations. The basic circuitry for both the a.c. and d.c. regulators is similar except that the d.c. regulator does not use the six phase rectifiers in the sensing circuit. Constant generator voltage output is obtained by having the regulating circuit change the voltage feed in response to an error signal.

A differential amplifier is used, in the error voltage detector circuit (fig. 19-21), to compare the generator output voltage, from the voltage sensing circuit, with a reference voltage, developed in the error voltage detector circuit, to produce the error signal. The error signal, acting through the modulator, modifies the timing of the pulse repetition frequency of the unijunction trigger circuits. The controlled pulses are fed to the respective field rectifier to control



111.144

Figure 19-21.—Voltage regulator, block diagram.

the average power to the generator field. The rate circuit modifies the error signal to stabilize the voltage regulator.

Voltage Sensing Circuit

The voltage sensing circuit (fig. 19-22) steps down the three phase generator 440 v.a.c. output thru voltage sensing transformer T1 to 25 v.a.c. Each phase is rectified by diodes CR1 thru CR6 and filtered by C1 and C2. This d.c. voltage is proportional to the generator output voltage. The d.c. voltage is applied to voltage divider network R1 thru R4 (R3 can be adjusted to develop the amount of voltage desired as the representative generator output) for comparison to the reference voltage in the error voltage detector circuit.

Error Voltage Detector Circuit

Transistors Q1 and Q2 (fig. 19-22) form a differential amplifier to compare the base voltages of the two transistors. The signal from the voltage sensing circuit is applied to the base of Q1, while the reference voltage is applied to the base of Q2. The reference voltage is applied via R8, which is a factory set and locked reference voltage adjustment.

Resistor R9 is the voltage dropping resistor for CR7, and capacitor C3 reduces the ripple and noise voltages across CR7 to provide a clean d.c. reference voltage. Resistors R6 and R7 are load resistors for transistor Q2.

Any difference between the input voltage at the base of Q1 and the reference voltage at the base of Q2 will produce an error signal (a change in collector current). If the input voltage is higher than the reference voltage, Q1 conducts heavier than Q2, and vice versa when the reference voltage is higher than the input. The voltage drop across R6 is the error voltage which is applied to the base of the modulator Q3.

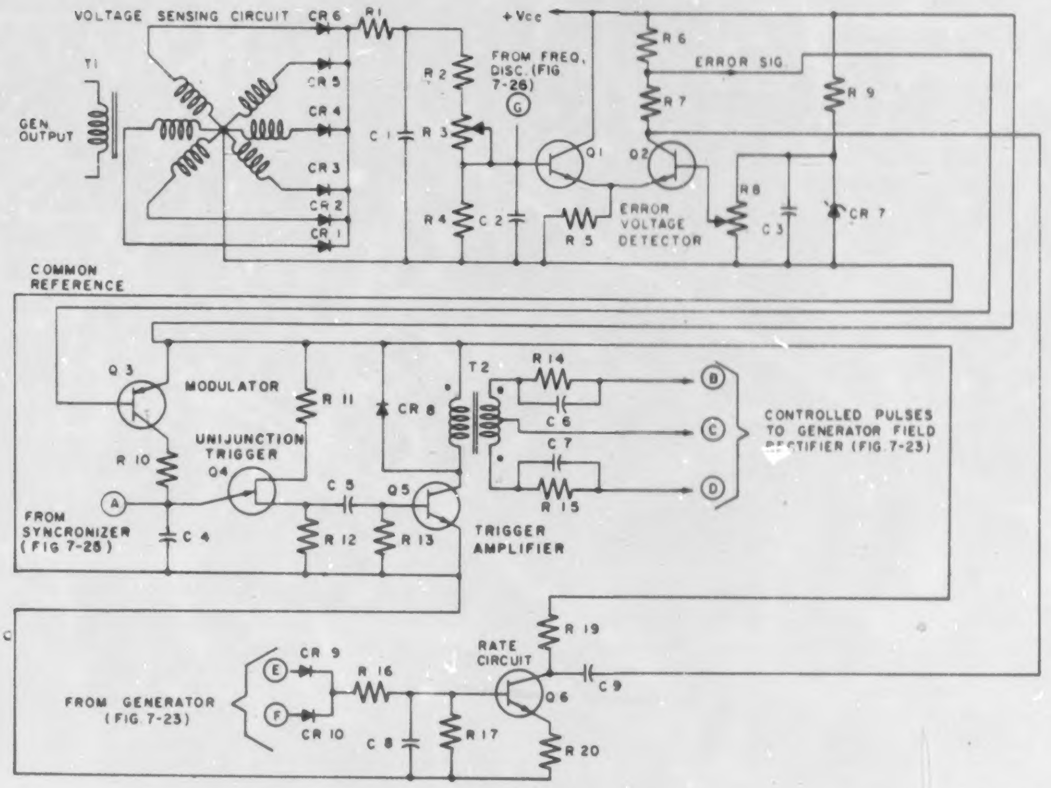
Modulator Circuits

The modulator circuit (fig. 19-22) modifies the time constant of the RC circuit (C4, R10, and the Q3 collector-emitter resistance). (The collector-emitter resistance is controlled by the current through resistor R6.) An increase in the error signal across R6 decreases the collector-emitter resistance of Q3 and thus decreases the charge time of C4. If the error signal increases, the charge time of C4 is increased.

Capacitor C4 discharges when the voltage across it is approximately 9 volts (the peak point voltage of unijunction transistor Q4). A synchronizing circuit (discussed later) clamps C4 to ground, thus delaying the RC time cycle. A rate feedback signal is also applied by the rate circuit to the collector of Q2. This signal modifies the error signal, thus stabilizing the voltage regulator.

Rate Circuit

The function of the rate circuit is to dampen the generator output voltage excursions about a set point. Otherwise the high gain of the voltage regulator would cause the generator output voltage to hunt. The method used for damping the voltage excursion is feeding back an inverted (opposite to the error signal) signal, proportional to the rate of voltage change.


VOLTAGE SENSING CIRCUIT
T1
GEN OUTPUT
CR 6
R1
CR 5
CR 4
CR 3
CR 2
CR 1
C 1
R 2
R 3
R 4
C 2
+Vcc
FROM FREQ. DISC. (FIG 7-26)
G
Q1
Q2
R 5
ERROR VOLTAGE DETECTOR
R 6
R 7
ERROR SIG.
R 9
R8
C 3
CR 7
COMMON REFERENCE
Q 3
MODULATOR
R 10
A
FROM SYNCRONIZER (FIG 7-25)
C 4
R 11
UNIJUNCTION TRIGGER
Q4
C 5
Q5
R 12
R 13
CR 8
T2
TRIGGER AMPLIFIER
R 14
C 6
C 7
R 15
B
C
D
CONTROLLED PULSES TO GENERATOR FIELD RECTIFIER (FIG 7-23)
R 19
RATE CIRCUIT
Q 6
C 9
R 20
R 17
C 8
R 16
CR 9
CR 10
E
F
FROM GENERATOR (FIG 7-23)

111.145

Figure 19-22.—Voltage regulator, simplified schematic.

The rate circuit (fig. 19-22) consists of a common emitter amplifier (Q6, R19, and R20) and an integrating circuit (R16 and C8). Resistor R17 is a discharge resistor for C8, and CR9 and CR10 are common rectifiers.

The input is supplied by the generator field rectifier (described later), integrated, and applied as forward base bias to Q6. Any change in the base is amplified and passed by C9 to the collector of the error detector, Q2. As this signal is opposite to the error signal, it will decrease conduction and stabilize the circuit.

Unijunction Trigger Circuit

The trigger function is performed by the unijunction trigger circuit (fig. 19-22). Unijunction transistor Q4 is a relaxation oscillator which initiates controlled rate pulses to trigger the field rectifiers. Q4 turns on when the voltage across C4 and the emitter current of Q4 reach preset values. When Q4 conducts, trigger pulses are applied to the trigger amplifier Q5.

Trigger Amplifier Circuit

The trigger amplifier (fig. 19-22) amplifies and shapes the trigger pulses. The circuit is a common emitter amplifier with RC input (R13 and C5) and transformer output (T2).

Transistor Q5 is protected against the inductive kickback voltage of T2 by diode CR8. Resistors R14 and R15 with capacitors C6 and C7 comprise a pulse shaping network to prolong the life of the SCRs in the field rectifier.

GENERATOR FIELD RECTIFIER

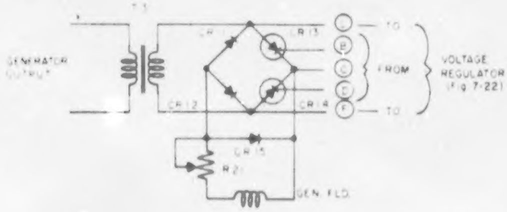
Both the a.c. and d.c. field rectifiers are similar in operation. The function of the generator field rectifier is to provide controlled d.c. power to the generator field in order to regulate the generator output voltage with the field power being proportional to the conduction line of the SCRs.

Transformer T3 (fig. 19-23) transfers voltage from the generator, which is rectified by the bridge rectifier (CR11 thru CR14). The conduction of the bridge is controlled by SCRs CR13 and CR14. One series combination of diode and SCR (CR11, CR13 or CR12, CR14) may conduct for alternate half cycles. The d.c. output is the controlled generator field power.

Diode CR15 is used as an inductive kickback diode to provide a path for the current generated by the collapsing magnetic field of the generator during the idle portion of each cycle. The amount of field power can be adjusted by R21.

The SCRs accomplish power control by the fact that they are rectifiers and in an a.c. circuit conduct only during half of each cycle. And then only after being turned on by a positive gate pulse (from the trigger amplifier). Power control is accomplished by switching the power on for a greater or smaller portion of the half cycle. Figure 19-24 shows how power can be increased as the firing point is moved along the phase time axis.

The firing point is determined by the position (or timing) of a spiked gate pulse. When applied to the SCR, the pulse turns it on. By controlling the phase of the gate pulse (with respect to the supply voltage) the firing (delay) angle of the SCR gate may be delayed to any point in the cycle up to approximately 180 degrees. Through control of the firing angle, the average power delivered to the load can be adjusted.



111.146

Figure 19-23.—Generator field rectifier, simplified schematic.

Referring to figure 19-24, it can be seen that by applying a gate pulse at zero degrees of the phase time axis (fig. 19-24A) output power will be applied during the complete half cycle. Figure 19-24B illustrates that power is obtained for a half of each half cycle by applying a pulse at 90 degrees of the phase time axis. The other extreme of no output when the phase delay is 180 degrees is represented in figure 19-24C.

SYNCHRONIZER

The function of the synchronizer is to assure that the firing angle is always reckoned from the instant the supply voltage crosses the zero axis at each positive half cycle (fig. 19-24A). As illustrated in figure 19-25, when the SCRs are not conducting, an alternate bridge rectifier circuit is. This alternate bridge consists of diode CR12, resistor R21, the generator field, resistors R23 and R22, diode CR16, and the secondary of T3 (solid allows). During the alternate half cycle, the patch (dashed arrows) is the same except diodes CR11 and CR17 are used.

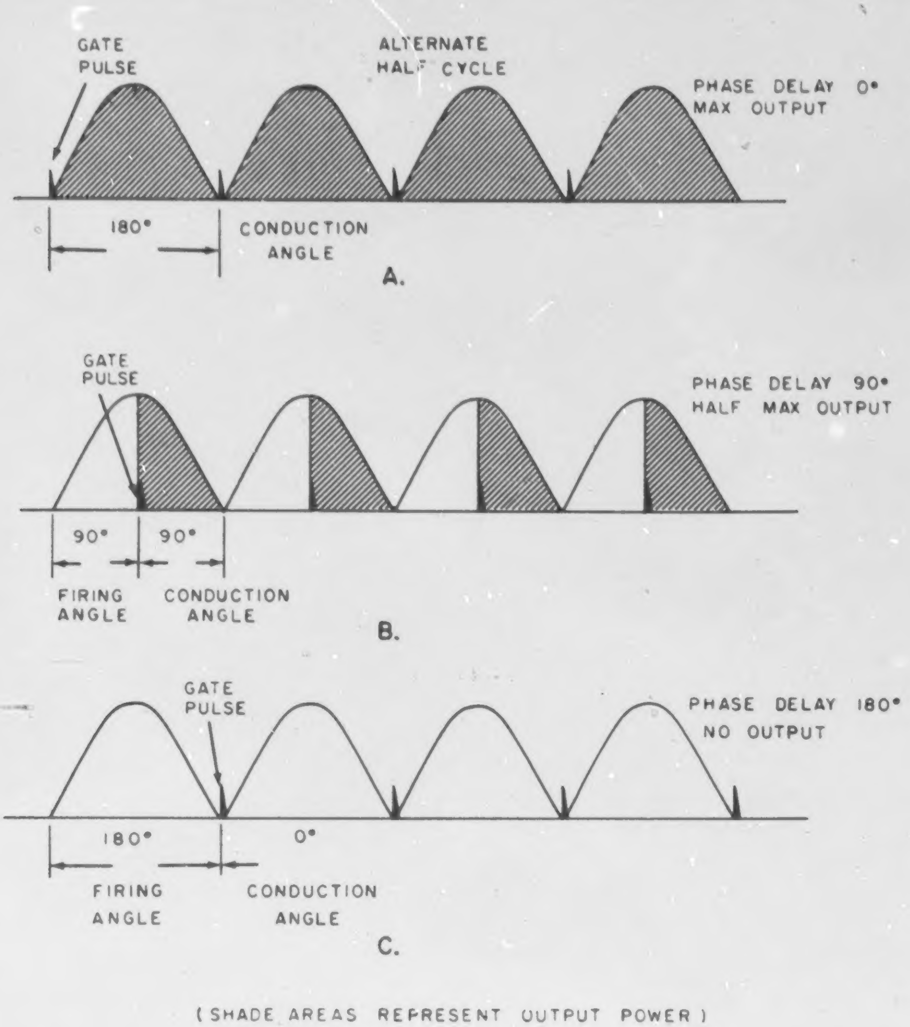
When the alternate bridge rectifier conducts, the voltage across R23 permits C4 (fig. 19-22) to charge, introducing the phase delay of the SCR gate pulse. Firing of SCRs CR13 and CR14 applies equal potential at both ends of voltage divider R22 and R23. This removes the voltage drop across R23 and thus allows Q7 to turn off and Q8 to turn on. Thus the timing capacitor C4 is clamped until the start of the next half cycle.

FREQUENCY DISCRIMINATOR

The speed/frequency regulator automatically maintains the motor speed, and the generator frequency at a preset value despite line variations or load changes.

Constant output frequency is obtained by automatically adjusting the power to the motor control field in response to a frequency discriminator. The frequency discriminator converts the generator output frequency to a voltage signal which is in direct proportion to the speed/frequency of the motor generator.

The speed/frequency regulator circuit is the same as the voltage regulator previously discussed. The operational difference is that the voltage regulator required an increase in generator output voltage to cause a decrease in generator field current, but in the frequency regulator an increase in frequency causes the field current to increase.

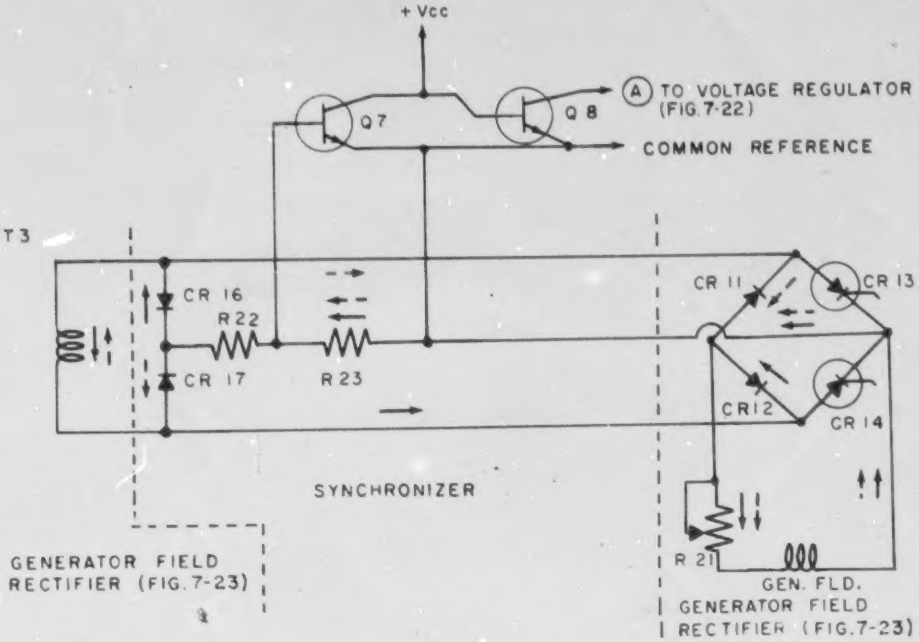

GATE PULSE
ALTERNATE HALF CYCLE
PHASE DELAY 0°
MAX OUTPUT
180°
CONDUCTION ANGLE
A.
GATE PULSE
PHASE DELAY 90°
HALF MAX OUTPUT
90°
90°
FIRING ANGLE
CONDUCTION ANGLE
B.
GATE PULSE
PHASE DELAY 180°
NO OUTPUT
180°
0°
FIRING ANGLE
CONDUCTION ANGLE
C.
(SHADE AREAS REPRESENT OUTPUT POWER)

111.147

Figure 19-24.—Phase shift of gate pulse.

The discriminator circuit is shown in figure 19-26. It essentially consists of a one show multivibrator which puts out a constant width pulse whenever a trigger pulse is applied. The trigger circuitry is designed so that a pulse is applied six times each output cycle in order to obtain a high enough sampling rate to decrease the response time of the circuit. The multivibrator output is integrated in order to provide a d.c. voltage that is proportional and linear with frequency.

The positive collector voltage input furnishes the circuitry operating biases and six phase a.c. is used to obtain the trigger pulses. The trigger circuitry consists of three single phase full wave rectifiers (CR18 & CR19, CR20 & CR21, and


+ Vcc
Q7
Q8
A TO VOLTAGE REGULATOR (FIG. 7-22)
COMMON REFERENCE
T3
CR 16
R22
CR 17
R23
CR 11
CR 13
CR12
CR 14
SYNCHRONIZER
R 21
GEN. FLD.
GENERATOR FIELD RECTIFIER (FIG. 7-23)
GENERATOR FIELD RECTIFIER (FIG.7-23)

111.148

Figure 19-25.—Synchronizer, simplified schematic.

CR22 & CR23). Each is driven from a winding of the T1 star secondary (fig. 19-22). The rectified voltages are clipped by the zeners (CR24, CR25, and CR26) to obtain a square pulse, which is further shaped by the differentiating circuitry of C10, C11, C12, and R24. The differentiated pulses drive the trigger transistor Q9, which saturates whenever a positive pulse is applied.

Transistors Q10 and Q11 form a one shot multivibrator whose output is a 2 millisecond wide pulse equal in amplitude to the collector voltage. Q11 is normally held on thru R27, CR27, and R28. Thus Q10 is held off as its base drive comes from Q11's collector. Since Q9 saturates when a trigger pulse is applied, the collector voltage of Q10 is at ground potential whenever a pulse is applied.

Before the trigger pulse is applied, C13 has been charged to the collector voltage (Vcc) level through resistor R25 with the other end clamped to ground thru diode CR27 and the base-emitter junction of Q11. When C13 discharges due to the trigger pulse, it turns Q11 off. The collector will rise to the collector voltage level and resistor R26 will apply base current to Q10 to hold it saturated after the trigger pulse ends.

This state (Q10 on, Q11 off) will exist until C13 charges thru R27 to a voltage high enough to allow Q11 to become forward biased again. At this time the output pulse ends since Q11 saturates and the base drive of Q10 is removed. The time duration of the output pulse is controlled by C13 and R27, with CR27 in the circuit to protect the base junction of Q11 from overvoltage.

The output pulse from the collector of Q11 is fed through resistor R29 to integrating capacitor C14. During the time no output pulse is present, C14 is discharged thru R29 and the collector-emitter junction of Q11. If the frequency of the generator increases, the ratio of charge time to discharge time increases, which in turn increases the discriminator output voltage proportional to the frequency shift. A decrease in frequency does the opposite. The output is applied

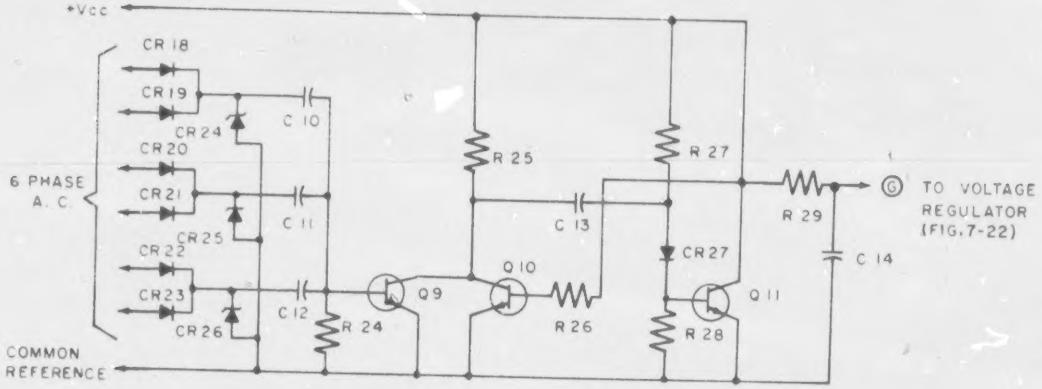


Figure 19-26.—Frequency discriminator, simplified schematic.

111.149

to the error voltage detector circuit (base of Q1, figure 19-22) or its equivalent in the frequency regulator.

MAINTENANCE

Under normal conditions, the motor generator set and control equipment require inspection and cleaning as designated by the PMS Maintenance Requirement Cards. When the motor generator is inspected, cleanliness, brush operation, condition of brushes and commutator, bearing temperature, and vibration should be observed.

When necessary, remove dust from the wound section with a vacuum cleaner, if available. If a vacuum cleaner is not available, either 30 psi maximum compressed air or a hand bellows may be used. Be certain that the compressed air does not have any grit, oil, or moisture content. Compressed air should be used with caution, particularly if abrasive particles (carbon, etc.) are present, since these may be driven into the insulation and puncture it or may be forced beneath insulating tapes or other possible trouble spots. If vibration exists, check for loose parts or mounting bolts.

When cleaning the control equipment, a vacuum cleaner or hand bellows should be used. Accumulations of dust or dirt around components can impair the natural flow and cause overheating.

DAMP WINDINGS

Moisture in windings can soften the insulation and reduce the dielectric strength. However, considerable time is usually required before the moisture will harm the windings. By checking the insulation resistance of the winding, possible trouble can be spotted and appropriate maintenance action taken.

If the insulation resistance falls below 1 megohm, the windings should be dried out. Three recommended methods of drying are oven drying, forced warm air drying, or low voltage current drying.

Oven drying is accomplished using a maximum temperatue of 85° C. The forced warm air method is simply using a fan to blow warm air across the damp windings. The air must be dry and should be in a vacuum with the temperature below 212° F.

The low voltage current method requires circulating a limited direct current through the windings. Care should be taken to ensure that the drying current does not exceed 80 percent of the full load rating. When drying the field winding, the brushes should be removed to prevent marking or pitting the collector rings (which can occur if the brushes carry the drying current.)

The insulation resistance should be checked at regular intervals. Remember that when using the current method the resistance may drop temporarily as the moisture is forced to the surface of the winding. Drying should continue until the resistance is at least 1 megohm. The drying process can take days in extreme cases. When the windings are dried out a coating of insulating varnish should be applied.

OIL-SOAKED WINDINGS

If oil enters the windings, insulation breakdown may be imminent, and the winding will probably have to be rewound. However, patches of oil should be removed with a clean cloth soaked in an approved solvent (chapter 2). Use the solvent sparingly, being careful that the insulation is not saturated as this can cause softening of the insulation. After cleaning with solvent one of the drying methods should be applied.

APPENDIX I

SECURITY

SECURITY

The security of the United States in general and of naval operations in particular depends partly on the success achieved in safeguarding designated official information which has been determined to require protection against unauthorized disclosure. This official information is called classified information.

A commanding officer is directly responsible for safeguarding all classified information within his command. He is also responsible for instructing his personnel in security practices and procedures.

Security is a protected condition that prevents unauthorized persons from obtaining classified information. Any matter, document, product, or substance that records or embodies this information is called classified material. Examples of classified material are publications, cipher keys, code books, letters, equipment, and messages in the three security classification categories: Top Secret, Secret, and Confidential.

PROGRAM MANAGEMENT

The security program at each command eligible to receive classified material is managed by a qualified military or civilian official. Commands employing U.S. Civil Service employees may designate civilian employees, GS-11 or above, as security managers. The duties of a security manager may be his only duties, his principal duties, or additional duties. He has sufficient staff assistance to carry out an effective program.

All security managers must preserve a balanced and common sense outlook toward providing the necessary level of protection against unauthorized disclosure in connection with the use, dissemination, storage, transmission, and destruction of classified information. The ideal objective is to indoctrinate personnel to the extent that they will be properly and automatically discrete in discharging their duties and will not consider security of classified information as something separate and apart from other things. Thus, security of classified information becomes a natural element of every task and not an additional one. Given sound direction from competent authority, this objective can be achieved by alert and cooperative personnel.

Security is a means - not an end. Rules that govern security do not guarantee protection, nor do they try to meet every conceivable situation. The law of diminishing returns limits the control measures that can be employed profitably, but it is possible to get a satisfactory degree of security with a minimum of sacrifice in operating efficiency.

ACCESS TO CLASSIFIED MATERIAL

The Department of Defense applies a security principle based on the control of dissemination of classified information. Therefore, knowledge or possession of classified information is permitted only to persons whose official duties require access in the interest of promoting national security, and only if the persons have been determined to be trustworthy. Access to classified material is defined as the ability and opportunity to know or possess this material. A person does not have access to classified material merely by being where it is kept, provided the security measures which are in effect prevent him from knowing or having this material.

PERSONNEL SECURITY CLEARANCES

Before a person can be given access, it must be determined that he is trustworthy, loyal, and of good integrity and character. Also, his habits and associations must indicate good discretion and judgment in the handling of classified information. To determine whether or not a person meets the criteria, or is eligible for access, two types of personnel security investigations are conducted: The National Agency Check (NAC) and the Background Investigation (BI). The determination that he is eligible for access to classified information is referred to as personnel security clearance.

PERSONNEL SECURITY INVESTIGATIONS

A National Agency Check consists of the review of the records and files of various Federal agencies for pertinent facts on the loyalty and trustworthiness of the person being investigated. The Background Investigation is designed to develop information as to whether the access to classified information by the person being investigated is clearly consistent with the interests of national security. The BI also inquires into the person's loyalty and trustworthiness.

GRANTING CLEARANCES

Based on the results of a completed NAC or BI, a security clearance is granted or denied by the commanding officer or other higher authority. An INTERIM or FINAL clearance is granted when certain requirements, which vary with the classification category, are met. Interim clearance is a determination of temporary eligibility for access to classified information. It is granted only when the delay in waiting for completion of the necessary steps for final clearance would be harmful to the national interests. Procedures to effect a final clearance are started at the same time as those for an interim clearance. FINAL clearance is granted when all required investigative procedures are completed, and the person is eligible for access to official information of a specific classification category; that is, Top Secret, or Confidential.

Each personnel security clearance, final or interim, is evidenced by the issuance of a Certificate of Clearance (OPNAV Form 5521-429) or equivalent record. This certificate or record becomes a permanent part of the person's service jacket.

NEED TO KNOW

Merely because an individual has been cleared for access to information of a certain classification category does not mean that he may have access to all classified information within that category. Classified information is made available to appropriately cleared personnel on a need-to-know basis.

NEED TO KNOW is the term given to the condition that a person must have access to classified information in order for him to carry out his official military or other governmental duties. Determining whether this condition exists and whether the person is authorized to receive access rests on the individual who possesses the information involved and not upon the prospective recipient. The need-to-know principle is applicable whether the prospective recipient is an individual, a command, a defense contractor, another Federal agency, or a foreign government. A need-to-know is recognized as established when ALL the following conditions exist. The disclosure is necessary in the interest of national defense; there clearly appears from the position, status, duties, and responsibilities of the applicant that he has a legitimate requirement for access to the classified information in order to carry out his assigned duties and responsibilities; there is no other equal or ready source of the same classified information available to him; and the applicant is or can be appropriately cleared for access to the degree of classified information involved and is capable both physically and mentally of providing the degree of protection which that information requires.

DISSEMINATION OF CLASSIFIED MATERIAL

Classified material may be disseminated at all agencies of the executive branch of the Federal Government. Top Secret material originated within the Department of Defense (DOD) is not disseminated outside DOD without the consent of the originator or a higher authority. Other classified material originated within DOD may be disseminated within the executive branch unless the originator specifically prohibits. Except under the rules established by the Secretary of Defense, classified material originated in a non-DOD agency is not disseminated outside DOD unless the originator consents.

DISSEMINATION TO PERSONNEL

Retired personnel and reservists in active status, regardless of rank, are not entitled to access to classified information merely by virtue of their present or former status. Limited access to classified material is to be granted them only when authorized by the Director of

Naval Intelligence. Physical custody of classified documents is not authorized.

Reserve personnel on active duty for training and flag or general officers in an active status may have access to classified information as necessary to perform their duties. They must be properly cleared, however, to handle classified information of the highest classification category involved. For the purpose of inactive duty training (drill periods), properly cleared reservists may be granted access to Confidential material as necessary to accomplish an assignment or prepare for a mobilization billet. They may be granted access to other classified material for specifically designated purposes only with the approval of higher authority. Classified information may be made available to agencies or persons outside the executive branch if they need that information to perform a function that will benefit the Federal Government, and the originator does not prohibit the release of the classified information.

Restraint on Reproduction

Parts of documents and materials containing Top Secret information is not reproduced unless the originator or a higher authority consents. All other classified material is reproduced sparingly, in the minimum number of copies; any stated prohibition against reproduction is observed strictly. By minimizing classified reproductions, the risk of compromise is decreased and storage costs are reduced. (Compromise is the known or suspected exposure of classified material to an unauthorized person.) Classified material is reproduced by specifically designated equipment only. If this equipment uses extremely sensitive reproduction paper, handle and store the paper in a way that prevents the image transfer of the classified information.

ACCOUNTABILITY AND CONTROL OF CLASSIFIED MATERIAL

Within DOD, there are established procedures for inventorying, accounting, and controlling Top Secret documents. At least once a year, the documents are inventoried. Either they are sighted physically, or accounted for by examination of written evidence of proper disposition, such as certificates of destruction or transfer receipts. When inventoried, each Top Secret document is page-checked for completeness and accuracy. Offices maintain accountability registers of Top Secret documents and also keep records on each document copy. These records show the document title, names of persons given access to information in the document, and the dates on which access was given. Each copy of a Top Secret document is numbered serially.

Administrative procedures or provisions also exist for controlling Secret material and protecting Confidential information. The accounting system for Secret material is determined by the practical balance of security and operating efficiency. As a minimum, this system records all Secret material that a command originates, receives, distributes or routes to its components, and disposes of by transfer of custody or destruction. The command provides protection for the Confidential information it receives, originates, transmits, or stores.

All incoming mail, bulk shipments, and messenger-delivered material are protected until it is determined that no classified material is contained therein. Screening points are established to ensure that incoming classified material is properly controlled and that access to classified material is limited to cleared personnel.

SAFEKEEPING AND STORAGE OF CLASSIFIED MATERIAL

Classified material may be used, held, or stored only where there are adequate facilities to prevent unauthorized persons from gaining access to it. The exact nature of security requirements depends on a security evaluation of local conditions and circumstances. A system of numerial evaluation has been developed to provide a uniform guide for establishing security protection of classified material in storage. The elements and application of this evaluation system are contained in OPNAVINST 5510.1D, chapter 5, section 1.

Vaults, safes, or file cabinets used to store classified material must always be kept locked unless protected by authorized personnel. Make it a habit to rotate the dials of all combination locks at least four complete turns in the same direction when securing vaults, safes, or file cabinets that are equipped with these locks. In most locks, if the dials are given only a quick twist, it is possible sometimes to open the locks merely by turning the dials in the opposite direction. Always make sure that all drawers of safes and file cabinets are held firmly in the locked position when they have been secured.

In using or holding classified material, you must be careful to keep unauthorized persons from gaining access to it. After removing classified documents from storage, keep them under constant surveillance and face down or covered when not working on them. Do not leave classified notes on memo pads or under desk blotters. As a matter of routine during working hours, immediately place in burn bags all classified rough drafts, shorthand notes, carbon paper, typewriter ribbons, and similar items that have served their purpose. At the close of each watch or working day, inventory all classified material that must be passed from watch to watch and transfer custody of it to the relieving watch supervisor. Check wastebaskets to see that they contain no classified material. Properly store all other classified material; store or destroy the burn bags.

If, when working with classified material, you are interrupted by a fire alarm or other emergency store the material in the same manner as at the close of a working day. It is your personal responsibility to safeguard all classified material in your possession.

TRANSMISSION OF CLASSIFIED MATERIAL

When Classified material must be moved physically, any means of transportation may be used except as follows:

- Commercial passenger aircraft moving to or from the area encompassed by the 48 contiguous States and the District of Columbia, Alaska and Canada, or from place to place outside this area. However, commercial passenger aircraft are authorized to carry or ship classified material on flights between this area and Hawaii and U.S. Territories or wholly within Hawaii and U.S. Territories.

- Foreign carriers on which the U.S. escort does not have physical control of the classified material.

Classified material is not carried across national borders unless the responsible official concerned determines that customs, postal, or other inspections will not be made.

Top Secret information may be transmitted by U.S. military personnel and Government civilian employees who have been cleared for access to this information. Persons whose primary duties involve the transmitting or escorting of Top Secret material will be specifically designated in writing. DOD contractor employees who have been specifically designated and approved in accordance with the Department of Defense Industrial Security Manual may also transmit Top Secret material, but only within U.S. boundaries. Moreover, Top Secret material may be transmitted by Armed Forces Courier Service, accompanied State Department diplomatic pouch, and appropriate electrical means.

Secret material may be transmitted by any of the means approved for transmitting Top Secret material as well as by appropriately cleared U.S. military and civilian personnel and by electrical means over approved communications circuits. Within and between the 50 states and the U.S. Territories, Top Secret material may also be transmitted by U.S. Postal Service registered mail.

Confidential material may be transmitted by any of the means approved for transmitting Secret material. However, U.S. Postal Service registered mail shall be used only for transmitting Confidential material of NATO, SEATO, and CENTO; FPO or APO addressees; and other addressees when the originator is not certain that they are located within U.S. boundaries.

Personnel in a travel status are allowed to carry classified material only in exceptional situations and where hand carrying is not otherwise specifically prohibited. In each instance, it must be determined that the traveler must have the classified information at his destination to perform his official duties.

As a result of hijackings, close attention must be given to the necessity of persons to travel by commercial passenger aircraft when they are hand carrying classified material.

COMPROMISE OF CLASSIFIED INFORMATION

Since the compromise of classified information presents a threat to the national security, the seriousness of the threat must be determined and action taken to minimize the adverse effects of the compromise. At the same time, appropriate measures must be taken to regain custody of the classified material and to identify and correct the cause of the compromise. Classified material is compromised when it becomes available to unauthorized persons through loss, theft, capture, recovery by salvage, defection of individuals, unauthorized viewing, or any other means. Any person who knows, or even suspects, the classified material has been compromised must report the circumstances to the appropriate authority.

If you find, for example, an unlocked container of classified material in the absence of assigned personnel, report the circumstances to the senior duty officer. Guard the container until he arrives. He will inspect this classified material, lock the container, and make a security violation report to the commanding officer. If he believes that classified information may have been compromised, he will require the person responsible for the container to return to his ship or station to make a definite inspection report.

Violations of regulations that pertain to the safeguarding of classified material but do not result in compromise are acted upon by the commanding officer of the persons involved without reference to higher authority. Persons found responsible for the compromise and those who violate security regulations are promptly and adequately disciplined. The fact that a security violation has occurred may be considered by the commanding officer sufficient justification for some form of formal disciplinary action.

DESTRUCTION OF CLASSIFIED MATERIAL

Classified material is destroyed as a matter of routine or in an emergency to prevent its capture by an enemy. When authorized or ordered, destruction must be complete. In routine destruction, the classified material consists of record or nonrecord documents that have served their purpose and waste material, such as handwritten notes, carbon paper, and typewriter ribbons. The cassified documents are destroyed in the presence of an appropriate official by burning, melting, chemical composition, pulping, pulverizing, shredding, or other approved means that will prevent recognition or reconstruction of the classified information. The classified waste material is likewise destroyed; however, no witnessing official is necessary. Aboard a ship that is severely disabled or in danger of sinking, the classified material is destroyed in accordance with the ship's emergency destruction bill. This bill details the method and order of destroying classified material.

APPENDIX II

GLOSSARY OF COMPUTER TERMS

ADDRESS—A coded number that specifically designates a computer register or other internal storage location. Information is referenced by its address. Portions of computer control are responsible for directing information to or from an addressed location.

AND GATE—See (gate, and).

BIT—A binary digit, zero or one, represented in the computer by the condition (set or clear) of a stage.

CODE—(1) A system of symbols for meaningful communication. (2) A system of symbols for representing data or instructions in a computer or a tabulating machine. (3) To translate the program for the solution of a problem on a given computer into a sequence of machine language or psuedo instructions and addresses acceptable to that computer. (4) A machine language program.

CODED PROGRAM—A procedure for solving a problem by means of a digital computer. The program may vary in detail from a mere outline of the procedure to an explicit list of instructions coded in machine language. See also (program).

CONTROL—The computer circuits that affect the carrying out of instructions in the proper sequence, the interpretation of each instruction, and the application of the proper commands to other sections and circuits in accordance with the interpretation.

DATA—Any or all facts, numbers, letters, and symbols, or facts that refer to or describe an object, idea, condition, situation, or other factors. It connotes basic elements of information which can be processed or produced by a computer. Sometimes data is considered to be expressible only in numerical form, but information is not so limited.

DECODER—(1) A device which determines the meaning of a set of signals and initiates a computer operation based thereon. (2) A matrix of switching elements which selects one or more output channels according to the combination of input signals present. Contrasted with (encoder).

DIGIT—One of a set of characters used as coefficients or powers of the radix in the positional notation of numbers.

FLIP-FLOP—(1) A bistable device; that is, a device capable of assuming two stable states. (2) A bistable device which may assume a given stable state depending upon the pulse of history of one or more input points and having one or more output points. The device is capable of storing a bit of information. (3) A control device for opening or closing gates, a toggle. Synonymous with (Eccles-Jordan circuit) and (Eccles-Jordan trigger).

FLOW CHART—A graphic representation of the major steps of work in process. The illustrative symbols may represent documents, machines, or actions taken during the process. The area of concentration is on where or who does what rather than how it is to be done.

GATE, AND—A signal circuit with two or more input wires in which the output wire gives a signal, if and only if, all input wires receive coincedent signals. Synonymous with (and circuit) and clarified by (conjunction).

GATE, OR—An electrical gate or mechanical device which implements the logical OR operator. An output signal occurs whenever there is one or more inputs on a multichannel input. An OR gate performs the function of the logical "inclusive OR operator." Symonymous with (OR circuit) and clarified by (disjunction).

INPUT/OUTPUT—A section providing the means of communication between the computer and external equipment or other computers. Input and output operations involve units of external equipment, certain registers in the computer, and portions of the computer control section. Abbreviated I/O.

INTERFACE—A common boundary between automatic data processing systems or parts of a single system.

LOOP—A self-contained series of instructions in which the last instruction can modify and repeat itself until a terminal condition is reached. The productive instructions in the loop generally manipulate the operands, while bookkeeping instructions modify the productive instructions, and keep count of the number of repetitions. A loop may contain any number of conditions for termination. The equivalent of a loop can be achieved by the technique of straight line coding, whereby the repetition of productive and bookkeeping operations is accomplished by explicitly writing the instruction for each repetition.

MATRIX—(1) Any logical network whose configuration is a rectangular array of intersections of its input-output leads, with elements connected at some of these intersections. The network usually functions as an encoder or decoder. (2) A circuit for separating a group of incoming signals into another group of signals which contain specific percentage levels of each of the incoming signals.

MEMORY—Same as (storage).

MODE—(1) A computer system of data representation, such as the binary mode. (2) A selected mode of computer operation.

NET—A network of interconnecting lines or circuits.

PROGRAM—(1) The complete plan for the solution of a problem, more specifically the complete sequence of machine instructions and routines necessary to solve a problem. (2) To plan the procedures for solving a problem; may include steps, such as the analysis of the problem, preparation of a flow diagram, preparing details, testing, and developing subroutines, allocation of storage locations, specification of input and output formats, and the incorporation of a computer run into a complete data processing system. Related to (routine).

ROUTINE—A set of coded instructions arranged in proper sequence to direct the computer to perform a desired operation or sequence of operations. A subdivision of a program consisting of two or more instructions that are functionally related; therefore, a program.

STORAGE—(1) The term preferred to memory. (2) Pertaining to a device in which data can be stored and from which it can be obtained at a later time. The means of storing data may be chemical, electrical, or mechanical. (3) A device consisting of electronic, electrostatic, electrical, hardware, or other elements into which data may be entered, and from which data may be obtained as desired.

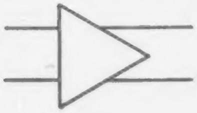
APPENDIX III

ELECTRONICS SYMBOLS

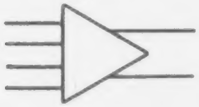
‡= LOCATION OF SYMBOL IN MIL-STD PUBLICATION

AMPLIFIER (2)‡

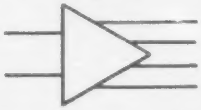
general



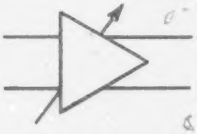
with two inputs



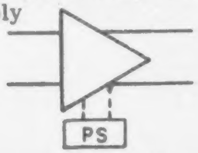
with two outputs



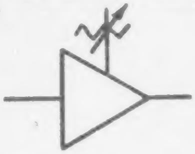
with adjustable gain



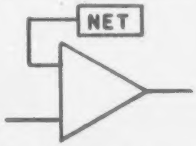
with associated power supply



with associated attenuator



with external feedback path

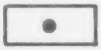


Amplifier Letter Combinations (amplifier-use identification in symbol if required)

BDG	Bridging
BST	Booster
CMP	Compression
DC	Direct Current
EXP	Expansion
LIM	Limiting
MON	Monitoring
PGM	Program
PRE	Preliminary
PWR	Power
TRQ	Torque

CIRCUIT ELEMENT (12)‡

general



Circuit Element Letter Combinations (replaces asterisk)

EG	Equalizer
FAX	Facsimile set
FL	Filter
FL-BE	Filter, band elimination
FL-BP	Filter, band pass
FL-HP	Filter, high pass
FL-LP	Filter, low pass
PS	Power supply

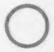
RG	Recording unit
RU	Reproducing unit
DIAL	Telephone dial
TEL	Telephone station
TPR	Teleprinter
TTY	Teletypewriter

Additional Letter Combinations (symbols preferred)

AR	Amplifier
AT	Attenuator
C	Capacitor
CB	Circuit breaker
HS	Handset
I	Indicating or switch board lamp
L	Inductor
J	Jack
LS	Loudspeaker
MIC	Microphone
OSC	Oscillator
PAD	Pad
P	Plug
HT	Receiver, headset
K	Relay
R	Resistor
S	Switch or key switch
T	Transformer
WR	Wall receptacle

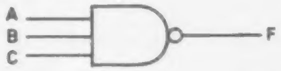
condition indicators

state (logic negation)

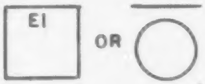


a logic Negation output becomes 1-state if and only if the input is not 1-state

an AND func. where output is low if and only if all inputs are high

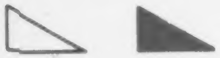


electric inverter



(elec. invtr. output becomes 1-state if and only if the input is 1-state)
(elec. invtr. output is more pos. if and only if input is less pos.)

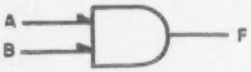
level (relative)



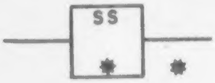
1-state is less +   1-state is more +

(symbol is a rt. triangle pointing in direction of flow)

an AND func. with input 1-states at more pos. level and output 1-state at less pos. level

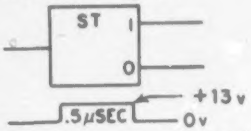


single shot (one output)

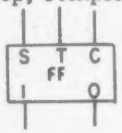


(waveform data replaces asterisks)

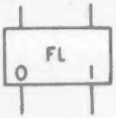
schmitt trigger, waveform and two outputs



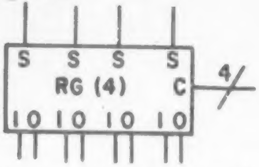
flip-flop, complementary



flip-flop, latch

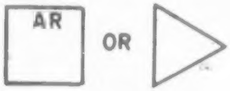


register

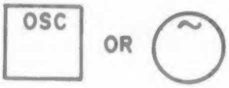


(binary register denoting four flip-flops and bits)

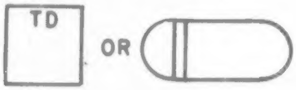
amplifier



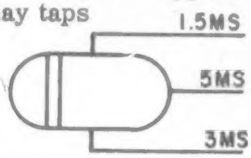
oscillator



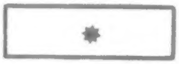
time delay



time delay with typical delay taps



functions not otherwise symbolized



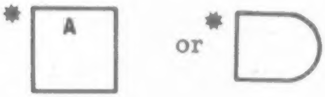
(identification replaces asterisk)

Logic Letter Combinations

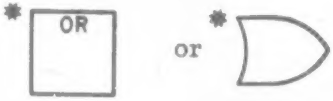
S	set
C	clear (reset)
T	toggle (trigger)
(N)	number of bits
BO	blocking oscillator
CF	cathode follower
EF	emitter follower
FF	flip-flop
SS	single shot
ST	schmitt trigger
RG(N)	register (N stages)
SR	shift register

LOGIC (left and righthand symbols are not mixed, asterisk denotes input side of logic symbol in general.)

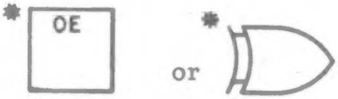
AND function



OR function



EXCLUSIVE-OR function



INDEX

A

Accessory equipment telephone, 260-264
  attendant's cabinet, 260-263
  fleet anchorage communications, 264
  lightning arrestor, 263
  shore-line connection boxes, 263
  shore-line control switch, 263
Accountability and control of classified material, 552
A-C generators operation, 105-108
  nonparallel, 106
  parallel, 106
  watchstanding, 107
A-C switchboards, 101
Adjustments for digital voltmeter, 143-145
Advancement qualifications, 2
Aerosol dispensers, 14
Aids, troubleshooting, 486
Air flow indicator and alarm panel (type IC/ASE), 414
Alarm and warning systems, 171
Alarm contact makers, 201
Alarm system, telephone, 256-260
Alarm systems, 189-191
  boiler temperature, 191
  carbon dioxide (CO_2) release, 191
  circulating-water, high-temperature, 190
  generator and generator bearing high-temperature, 190
  lubricating-oil, low-pressure, 189
  sprinkling, 189
Alarm systems, fire, 180-187
Alarm systems maintenance, 192
Amplifier AM-2210/WTC, sound-powered telephone, 168-170
Amplifier, synchro signal, 362-371
Analyzer, dead reckoning, 419-422
  distance converter, 419
  roller carriages, 420
  ship's course crank arm mechanism, 422
Announcing and intercommunicating systems, 193-234
Announcing systems, 199-201
Annunciators, 167
Audio amplifier, 168
Audio oscillator, 133
Automatic correction devices, 338-340
  damping eliminator, 339
  speed corrector, 339
Automatic switchboard equipment, 243
Azimuth control system, 350-355

B

Ballistic deflection error, 338
Bandwidth, 517
Basic selector system, 248
Bearings, 463-465
Blocked text, 488
Boiler temperature alarm system, 191
Brushes, 465-472
Burner order indicator system, 378-382
  setting synchros, 381
  standard synchro connections, 381
Burns, 27-30
Bus-transfer equipment, 101

C

Cables, electrical, 61-85
Call-bell systems, 163
  annunciators, 167
  circuit A, 165
  circuit E, 163
Carbon dioxide (CO_2) release alarm system, 191
Care and upkeep of IC equipment, 459-461
  cleaning electronic equipment, 461
  cleaning practices, 459
  lubrication, 460
  painting and varnishing, 460
Career challenges for the IC Electrician, 1-7
Cartridges, 293
Casualty power system, 108
  rigging and unrigging, 109

Cathode-ray tubes, 16
Central amplifier announcing system, 201-216
  alarm contact makers, 201
  audio amplifier cabinet, 203-206
  central amplifier system, 202
  control rack, 211-216
  loudspeaker groups, 202
  maintenance of, 208-211
  operation of, 206-208
  power rack, 216
Central operations systems, 510-515
Centrifugal tachometer, 126
Circuit classification by readiness, Table 4-1, 86
Circuits, distance transmitter, 428-433
Circuits, sound-powered telephone, 153-162
  highline, 162
  string type, 161
  switchboard, 153
  switchbox, 158
  X40-J-casualty communications, 162
Circuits, transistorized and printed, 474-486
Circulating-water, high-temperature alarm system, 190
Classification codes, Navy Enlisted, 2
Classified material, 550-554
  access to, 550
  accountability and control, 552
  compromise of, 553
  destruction of, 554
  dissemination of, 551
  safekeeping and storage, 552
  transmission of, 553
Cleaning solvents, 16
Clearances, personnel security, 550
Closely regulated power supplies, 520-549
Combustion gas and smoke detector system, 187
  basic circuit, 187
  operating principles, 187
Commercial tape recorder reproducers, 301
  modes of operation, 301
Communications system, interior voice, 497-506
Communicators and collector rings, 469
Comparison curve, 318
Compass, starting, 340
Compass, stopping, 341
Compromise of classified information, 553
Computer terms, glossary, 555
Connections, telephone, 249-253
Contactors, 46
Control console, ship's, 372-374
Control console, steering, 374
Control equipment, 522
Control program, 504
Control rack, 211-216
Corrective maintenance, 458
Course followup circuits, 429
Course to steer indicator, 375
Crimping, 474

D

Damping eliminator, automatic, 339
Damp windings, 548
Dead reckoning analyzer indicator, MK 9, 439
Dead reckoning equipment, 419-428
  analyzer, 419-422
  indicator, 422
  maintenance, 428
  operation, 428
  tracer, 423
Dead reckoning tracer MK 5 Mod 4 B, 436
Demagnetizing tape heads, 303
Destruction of classified material, 554
Dial telephone systems, Part I, 235-273
Dial telephone systems, Part II, 274-288
  description of equipment, 274
  lifefinding principles, 281-286
  main assemblies of switchboard cabinet, 274-277
  main assemblies of system cabinet, 277
  sample call, 286
  system operation, 278-281
Digital voltmeter, model 481, 140-145
  feedback voltage linearity test, 143
  front panel controls and indicators, 142
  gain setting, 142
  hum control adjustment, 143
  operation principles, 141
  range unit adjustment, 144
  standardization adjustment, 143
Disk and roller assembly, friction, 383
Dissemination of classified material, 551
Distance transmitter circuits, 428-433
  course followup, 429
  electrical troubles, 433
  pencil-magnet and projector-light circuits, 433
  step transmitter, 429
Distribution systems, power, 86-113
  emergency power, 104
  ship's service power, 100-104
DRE improvements, 434
  tracer, 423
Dummy log, 415
  distance transmitter, 416
  operation, 417
  speed transmitter, 415

E

Electrical cables, 61-85
  assembly, 84
  coaxial cable, 81
  coaxial cable connectors, 82
  color codes, 65
  comparison guide, 62
  designating cable connectors, 83
  maintenance, 68
  marking, 65
  nonflexing service, 64
  repair and installation, 69-80
  repeated flexing service, 64
  terminal marking, 67
  type and size designations, 63
Electric shock, 19-23
Electrical fires, 17-19
Electrical zero, 367
Electro-magnetic indicator, 413
Electromechanical unit, 364
Electron tubes, radioactive, 15
Electron tubes, replacement, 10
Electronic equipment cleaning, 461
Electronics symbols, 557-559

Emergency power distribution system, 104
  feedback tie, 105
  preferred and alternate sources of power, 105
Engine order system, 372
Entertainment system, ship's, 233

Equipment, 148
  handling and stowage, 150
  handsets, 149
  headsets, 149
  repairs, 151
Equipment, sound, 193
Equipment, telephone, 235
Equipment, test, 114-146
Erasing magnetic tape, 303

Error correction, 336-338
  ballistic deflection error, 338
  speed-course-latitude error, 336
  tangent latitude error, 336

F

FIN stabilizer systems, 506-510
  general description, 506
  operation principles, 507

Fire alarm systems, 180-187
Fires, electrical, 17-19
Fleet anchorage communications, 264
Free gyroscope, 305-310
  apparent rotation of, 308
  effect of earth's rotation, 307
  force of translation, 307
  properties, 305
  three degrees of freedom, 305
Frequency regulator, 522
Friction disk and roller assembly, 383
Fuse panel, 255

G

Gas and smoke detector system, combustion, 187
Generator and generator bearing high-temperature alarm systems, 190
Generator field rectifier, 545
Generator operation, A-C, 105
Glossary of computer terms, 555
Gravity reference system, 348-350
Grounding, 10
Gyrocompasses, Part I, 305-342
Gyrocompasses, Part II, 343-371
Gyrocompasses, stabilizing, 313
Gyroscope, free, 305-310

H

Handsets, 149
Handtools, 13
Handtools, common, electric, 463
Headsets, 149
Helm angle indicator, 378
High latitude modification, 342
Highline circuits, 162

I

IC Electrician career challenges, 1-7
IC Electrician rating, 1
IC Electrician responsibilities, 1
IC switchboards, 86
IC systems, classifications, 86
Indicating systems and ship's control order, 372-382
Indicator, dead reckoning, 422
  latitude correction mechanism, 422
Indicators, overload, 99
Indicators, ship's, 374-378
  course to steer, 375
  helm angle, 378
  rudder angle order, 375
  ship's course, 374
Indicator system, salinity, 407-413
Indicator-transmitter, 403

Information sources for rating, 5
  DOD information security program regulation, 6
  Naval training (NAVEDTRA) publications, 5
  periodicals, 6
  technical manuals, 6
Installations equipment, new, 497-519
Intercommunicating and announcing systems, 193-234
Intercommunicating systems, 216-228
  intercommunicating units, 227
  maintenance of, 225
  operation of, 221
Interior communications switchboards, types of, 86
  dead-front, 86
  dead-front, front-service, 87
Interior communications systems classification, 86
Interior voice communications system, 497-506
  block diagram and description, 497
  control program, 504
  line and net matrices, 501
  matrix control, 501
  power system, 504
  program control, 500
  redundance and switchover control, 503
Inverter, static, 530-536
Investigations, personnel security, 551

L

Leveling control system, 355
Lightning arrestor, 263
Line and net matrices, 501
Line disconnect key panel, 256
Line finding, 245
Line grouping, 244
Log, dummy, 415
Log system, underwater, 400-407
Loudspeakers, 196-199
Lubricating-oil, low-pressure alarm system, 189

M

Magnetic tapes, 303
  demagnetizing, 303
  erasing, 303
  splicing, 303
Magneto-voltmeter-type equipment, 390
Maintenance, 112, 458-496
  bus transfer equipment, 113
  generators, 112
  preventive and corrective, 458
  switchboards, 113
Maintenance, relay, 47
Maintenance techniques, 472-474
  crimping, 474
  soldering, 472-474
Making a gyroscope a gyrocompass, 310-313
Mandatory turn-in repairables, 461
Matrix control, 501
Meggers, 124
Megohmmeter, type CV-60089, 124
Metering and indicating systems, ship's, 383-418
Microphones, 193-195
MK 9 dead reckoning analyzee indicator, 439
MK 23 gyrocompass controls, 348
Monitor circuits, 542
Motor generator, 520
Multimeters, 115-121
  AN/PSM-4(Series), 115-120
  vacuum tube voltmeters, 120

N

Navy Enlisted classification codes, 2
NC-2 plotting system, 438
New installations equipment, 497-519
No-break power supplies, 539-548
  components, 539
  frequency discriminator, 545
  generator field rectifier, 545
  monitor circuits, 542
  operation, 540
  synchronizer, 545
  voltage regulator, 542-545
Nonpendulous stabilizing, 315
Numbering, 244

O

Oil-soaked windings, 549
Operation principles, sound-powered telephones, 147
Oscilloscope, 129
Overload indicators, 99

P

Parallel operation, 529
Pencil-magnet and projector-light circuits, 433
Pendulous stabilizing, 313
Personnel security clearances, 550
Personnel security investigations, 551
Phase sensitive voltmeter, 145
Plotting systems, 419
Plotting table NC-2 Mod 2, 451

Portable electric power tools, 461-472
  bearings, 463-465
  brushes, 465-472
  common handtools (electric), 463
  inspecting and testing, 462
  vacuum cleaner, 462

Power distribution switchboards, 109-112
  bus ties, 112
  control benchboard, 109
  ground detector lamps, 110
  ship's service switchboard, 110
Power distribution systems, 86-113
Power distribution systems, ship's service, 100
Power equipment, 264
Power rack, 216
Power sensing network, 528
Power signal relay, 253

Power supplies, 520-548
  closely regulated, 530-549
  no-break, 539-548
  rectifier, 536-539
  types of, 520-530
Power system, casualty, 108
Power tools, 13
Power tools, portable electric, 461-472
Preventive maintenance, 458
Program management, 550

Propeller revolution indicator system, 385
  magneto-voltmeter-type equipment, 390
  maintenance, 392
  synchro type equipment, 386-390

Protective devices, 48-61
  circuit breakers, 53-60
  fuses, 48-51
  overload relays, 60
  troubleshooting fused circuits, 51

Public address sets, 228-233
  AN/PIC-2, 228
  lectern type, 232

Q

Qualifications for advancement, 2

R

Radioactive electron tubes, 15
Rating, IC Electrician, 1
Receivers, color, 519

Record players, 293
  cartridges, 293
  tone arms, 294
  turntables, 294

Rectifier power supply, 536-539
  functional description, 536
  maintenance, 539
  operation, 536
  safety, 536-539
Redundance and switchover control, 503
Regulated power supplies, 520-549
Relay maintenance, 47
Relays, 44-47
  kinds of, 44-46
  maintenance of, 47
Relays and switches, 171-180
Repairables, mandatory turn-in, 461
Requirements, safety, 8-11
Responsibilities of today's IC Electrician, 1
Rigging and unrigging casualty power cables, 109
Rubber floor matting, 11
Rudder angle order indicator, 375
Rudder angle order transmitter, 376
Rules of study, 6

S

Safekeeping and storage of classified material, 552
Safety, 8-30
Safety requirements, 8-11
Safety shorting probe, 11
Salinity cell and valve assembly, 408
Salinity indicator panel, 409
Salinity indicator system, 407-413;
  cell and valve assembly, 408
  indicator panel, 409
  maintenance, 412
Scanning, 516
Schematic, blocked, 488
Schematic diagrams, 486
Sea valve and rodmeter, 400
Security, 550-554
Security clearances, personnel, 550
Security investigations, personnel, 551
Shipboard announcing systems, Table 8-1, 200
Ship's control console, 372-374
  engine order system, 372
  propeller revolution order system, 372
  speed lights, 374
Ship's control order and indicating systems, 372-382
Ship's course indicator, 374
Ship's entertainment system, 233
  components, 233
  operation, 234
Ship's metering and indicating systems, 383-418

Ship's service power distribution system, 100-104
  A-C switchboards, 101
  bus-transfer equipment, 101
  lighting, 101
  multipurpose power outlets, 104
  phase sequence, 104
  shore power connection, 104
Shock, electric, 19-23
Shore-line connection box, 263
Shore-line control switch, 263
Shore power connection, 104
Signal generators, 133-140
  audio oscillator, 133
SIMM, 486-496
Soldering, 472-474
Soldering irons, 13
Solenoids, 42-44
Sound equipment, 193
  loudspeakers, 196-199
  microphones, 193-195

Sound-powered telephone amplifier AM-2210/WTC, 168-170
  audio amplifier, 168
  maintenance, 169
  power supply, 169
  switching circuit, 168
Sound-powered telephone circuits, Table 6-1, 154-157
Sound-powered telephone systems, 153-163
  circuit X40J-casualty communications, 162
  highline circuits, 162
  maintenance, 163
  selector and transfer switches, 161
  stringtype circuit, 161
  switchboard circuit, 153
  switchbox circuit, 158
Sound-powered telephone systems glossary, Table 6-2, 158
Sound-powered telephones, 147-170
  handset, 149
  headset, 149
Sound-powered units, 147
  principles of operation, 147

Sound recorder-reproducer set AN/UNQ-7E, 294-301
  equipment cabinet, 295
  operation of, 299
  remote control unit, 298
  tape transports, 298
Sound recording and reproducing systems, 289-304
Sources of information for rating, 5
Speed corrector, automatic, 339
Speed-course-latitude error, 336
Speed indicator and wind direction system, 392-400
Speed lights, 374
Sperry MK 11 Mod 6 gyrocompass, 318-335
  control and alarm system, 324
  followup system, 330
  mercury ballistic, 322
  phantom element, 323
  sensitive element, 318
  spider, 323
  transmission system, 332

Sperry MK 23 Mod 0 gyrocompass, 343-362
  alarm bell and annunciator, 348
  alarm control, 348
  azimuth control system, 350-355
  control cabinet, 346
  followup system, 356-359
  gravity reference system, 348-350
  gyro records and log entries, 362
  leveling control system, 355
  maintenance, 362
  master unit, 343-346
  MK 23 gyrocompass controls, 348
  operation, 359
  speed unit, 346-348
Sprinkling alarm system, 189
Stabilizer systems, FIN, 506-510
Stabilizing gyrocompass, 313-318
  comparison curve, 318
  nonpendulous method, 315
  pendulous method, 313
Static exciter, 524-528
Static inverter, 530-536
  description, functional, 531
  maintenance, 536
  operating procedure, 536
  operation cycle, 535
Station equipment, telephone, 235
Steel wool, 12

Steering control console, 374-378
  course to steer indicator, 375
  helm angle indicator, 378
  rudder angle order indicator, 375
  rudder angle order transmitter, 376
  ship's course indicator, 374
  steering emergency signal circuit, 378
Steering emergency signal circuit, 378
Step transmitter circuits, 429
Stickoff current, 365
String type circuits, 161
Stroboscopic tachometer, 127
Study rules, 6
Supplies, types of power, 520-530
Switchboard circuits, 153
Switchboard equipment, automatic, 243

- Switchboard sections, 88-98
  - action cutout (ACO), 92
  - distribution, 88
  - local IC, 93
- Switchboards power distribution, 109-112
- Switchbox circuits, 158
- Switches, 31-42
  - knife, 31
  - lever-operated, 38
  - maintenance of, 42
  - mechanical, 39
  - pile, 33
  - pressure, 39
  - pushbutton, 32
  - rotary selector, 34
  - rotary snap, 32
  - thermostatic, 39
  - toggle, 32
  - water, 41
- Switches, protective devices, and cables, 31-85
- Switches and relays, 171-180
  - audible signals, 171
  - visual signals, 175
- Switching, 244-260
  - alarm system, 256-260
  - basic 100-line finder-connector system, 246-248
  - basic 100-line system, 245
  - basic selector system, 248
  - fuse panel, 255
  - line disconnect key panel, 256
  - line finding, 245
  - line grouping, 244
  - maintenance, 266
  - numbering, 244
  - power signal relay, 253
  - ringing machines, 254
  - telephone connections, 249-253
  - types of calls, 254
- Switching circuit, 168
- Switchover and redundance control, 503
- Symbolic Integrated Maintenance Manual (SIMM), 486
  - blocked schematic, 488
  - blocked text, 488
  - improvements, 496
  - indexing of related information, 494
  - maintenance dependency chart, 490
  - operating procedures, 489
  - parts location and identification, 494
  - precise-access blocked diagram, 489
  - repair of mechanical assembly, 494
- Symbols, electronics, 557-559
- Synchro signal amplifiers, 362-371
  - alarm switch, 366
  - electrical zero, 366
  - electromechanical unit, 364
  - electronic component, 363
  - frequency of input signal, 366
  - maintenance of, 366
  - stickoff current, 365
  - zeroing a resolver, 370
  - zeroing methods, 367
  - zeroing multispeed synchro systems, 370
- Synchro type equipment, 386-390
- Synchronizer, 545

T

- Tachometer, 125-133
  - centrifugal, 126
  - oscilloscope AN/USM-105A, 129
  - stroboscopic, 127
- Tangent latitude error, 336
- Tank level indicators, 413
  - air flow indicator and alarm panel (type IC/ASE), 414
  - electro-magnetic indicator, 413
- Tape recorder maintenance, 302
  - demagnetizing tape heads, 303
  - erasing magnetic tape, 303
  - mechanical adjustments, 302
  - splicing magnetic tape, 303
- Tape recorder/reproducers, commercial, 301
- Tape transports, 298
- Techniques for sound recording and reproducing, 289-293
  - magnetic, 291
  - mechanical, 289
  - photographic, 289
- Techniques, maintenance, 472-474
- Telephone circuits, 242
- Telephone connections, 249-253
- Telephone equipment, 235
- Telephone inspections, 267
- Telephone line station repairs, 267
- Telephone, sound-powered, 147-170
- Telephone systems, dial, Part II, 274-288
- Telephone station equipment, 235
  - handsets, 236-242
  - telephone circuits, 242
  - types of telephones, 235
- Television, 515
  - bandwidth, 517
  - color receivers, 519
  - frequencies, 517
  - scanning, 516
  - transmission, 517

Television — continued
  TV cameras, 517
  video tape recordings, 519
Test equipment, 114-146
Testing equipment, 268
Tone arms, 294
Tracer, dead reckoning, 423-428
  auxiliary plotting board, 428
  chart board, 427
  tracking mechanism, 425
Transistorized and printed circuits, 474-486
  printed circuits, 478
  servicing precautions, 477
  testing transistors, 476
  troubleshooting transistor circuits, 475
Transmission of classified material, 553
Troubleshooting, 114
Troubleshooting aids, 486
  one-function diagrams, 486
  schematic diagrams, 486
  servicing block diagrams, 486
  voltage distribution diagrams, 486
  voltage and resistance charts, 486
Troubleshooting transistor circuits, 475
Tube testers, 121-124
Turn-in repairables, mandatory, 461
Turntables, 294
Types of power supplies, 520-530
  control equipment, 522
  frequency regulator, 522
  maintenance, 530
  motor generator, 520
  parallel operation, 529
  power sensing network, 528
  safety, 529
  static exciter, 524-528
  voltage regulating system, 524

U

Underwater log system, 400-407
  indicator-transmitter, 403
  principles of operation, 405
  remote control unit, 407
  sea valve and rodmeter, 400
Units, sound-powered, 147
Upkeep and care of IC equipment, 459

V

Valve position indicator system, 378-382
  setting synchros, 381
  standard synchro connections, 381
Video tape recordings, 519
Voltage and resistance charts, 486
Voltage distribution diagrams, 486
Voltage regulating system, 524
Voltmeters, 140-146
  digital, 140-145
  phase sensitive, 145
Voltmeters, vacuum tube, 120

W

Warning and alarm systems, 171-192
Warning signs, plates, and tags, 24-26
Wind direction and speed indicator system, 392-400
  type B equipment, 393-400
Windings, 548
  damp, 548
  oil-soaked, 549
Workbenches, 26

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